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United States/Canada Air Quality Agreement

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Abstract: The Canada-United States Air Quality Agreement, signed March 13, 1991, marked a new era of cooperation aimed at helping to guarantee cleaner air and a healthier environment for millions of Canadians and Americans. Now, one year later, progress has been made by each country, individually and together. A forum for discussion has been established; programs to resolve domestic and transboundary air quality issues are being developed, and information about them is being shared; lessons learned from existing and past programs also are being shared; and the pursuit of data compatibility between countries is under way.

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United States/Canada Air Quality Agreement

PROGRESS REPORT

MARCH 1992

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GOVERNMENT OF
THE UNITED STATES OF AMERICA
AND GOVERNMENT OF CANADA

President Bush and Prime Minister Mulroney sign the U.S.-Canada Air Quality Agreement on March 13, 1991.

United States/Canada Air Quality Agreement

PROGRESS REPORT

March 1992

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Executive Summary

The Canada-United States Air Quality Agreement, signed March 13, 1991, marked a new era of cooperation aimed at helping to guarantee cleaner air and a healthier environment for millions of Canadians and Americans. The signatures of the Canadian Prime Minister and the American President served to underline its significance. Now, one year later, progress has been made by each country, individually and together. A forum for discussion has been established; programs to resolve domestic and transboundary air quality issues are being developed, and information about them is being shared; lessons learned from existing and past programs also are being shared; and the pursuit of data compatibility between countries is under way.

THE AIR QUALITY COMMITTEE

A Canada-U.S. Air Quality Committee and two working subcommittees were created in 1991. One subcommittee oversees the implementation of the Agreement and works on, among other things, emission inventories, control technologies, and market-based mechanisms. The second subcommittee focuses on scientific and technical activities, including atmospheric and effects research and monitoring. The committee and the two subcommittees met in 1991, and more meetings are planned for 1992. The subcommittees will meet on a regular basis to exchange information and initiate the programs called for in the Agreement.

The United States and Canada are sharing information on the implementation of their respective control programs, including the use of market-based control mechanisms in the United States to achieve more cost-effective emissions reductions.

Sulphur Dioxide Emission Reduction Goals and Program

Canada has committed to reduce sulphur dioxide (SO_2) emissions by 40 percent from 1980 levels in the seven easternmost provinces to 2.3 million tonnes (1 tonne is equal to 1.1 tons) by 1994. About 80 percent of these reductions are now in place. A permanent national cap also has been set for sulphur dioxide emissions at 3.2 million tonnes by the year 2000.

Specific milestones achieved in 1991 include:

- A commitment by New Brunswick and Ontario utilities to equip nearly 1,800 megawatts of power plant capacity with wet limestone scrubbers.
- The completion of major new facilities at Canadian smelters notably at Rouen Noranda, Quebec, and at Timmins, Ontario, which has led to more efficient capture of sulphur dioxide as sulphuric acid for resale.
- Construction and testing of new power plant combustion and emission control technologies at sites in Nova Scotia and Saskatchewan.
- The beginning of work between the federal and provincial governments towards the development of agreements for the year 2000 national cap.

The United States is committed to reducing annual SO_2 emissions by about 10

million tons by the year 2000 and to achieving a permanent national cap of 8.95 million tons of sulphur dioxide per year for electric utilities by 2010. For the United States, this is about a 40 percent reduction in emissions from 1980 levels. The emissions reductions required by the U.S. control program begin on January 1, 1995. Phase I of the control program, which runs through 1999, will contribute to annual reductions in SO_2 from 1980 levels of approximately 5 million tons. Finally, annual industrial emissions of sulphur dioxide in the United States are not to exceed 5.6 million tons.

In 1991, the United States promulgated final rules on the auction and direct sale of SO_2 emission allowances and proposed rules in four areas of critical importance to the acid rain program: sulphur dioxide allowances, acid rain permits, continuous emissions monitoring, and excess emissions. The United States is in the process of developing the remaining rules to implement the acid rain control program.

Nitrogen Oxides Programs

Both countries are seeking to reduce nitrogen oxides (NOx) emissions from both stationary (e.g., power plants) and mobile (e.g , passenger cars) sources.

In Canada, the commitment is to reduce NOx emissions at stationary sources by 100,000 tonnes from a forecasted emission level of 970,000 tonnes in the year 2000. Measures to achieve these reductions are being developed and implemented under Canada's National Management Plan for controlling NOx and VOC emissions that cause smog.

In the United States, a NOx control program is being implemented to reduce total annual emissions of NOx by about 2 million tons from 1980 levels. Rules are being developed to reduce NOx emissions from power plants and additional sources subject to the ozone non-attainment provisions of the Clean Air Act.

Both countries are tightening automobile NOx emissions standards. In the United States, regulations implementing tighter standards for passenger cars were promulgated in June 1991, to take effect beginning in the 1994 model year. In Canada, Transport Canada announced in February 1992 a formal agreement with major automobile manufacturers on voluntary compliance with standards for passenger cars. The agreement provides for a phase-in of equivalent standards in the same time frame as that required by the U.S. Clean Air Act.

Scientific and Technical Cooperation

In this report, the two countries focused primarily on scientific and technical activities related to acidic deposition including:

- Emission inventories: the coordination of emission inventory development relative to sulphur dioxide and nitrogen oxides for 1980, 1985, and 1990 (preliminary) are included.

- Atmospheric modeling: cooperation between the two countries regarding atmospheric model application, evaluation, and development is described. Historical and projected deposition levels, including levels assuming full implementation of the Canadian and U.S. acid rain control programs are included.

- Deposition monitoring: the monitoring of wet and dry deposition of sulphur and nitrogen compounds is carried out by federal, provincial, state, and private sector groups. Maps of deposition levels and trends information are included.

- Effects research and monitoring: the effects of acidic deposition on lakes and streams, forests, materials, and human health are discussed. Effects monitoring is discussed in several areas.

- Control technologies: the report discusses the efforts of the two countries in developing and deploying pollution control technologies aimed at reducing acidic deposition.

- Market-based incentives: the U.S. acid rain control program is employing incentives to help reduce the cost of emissions reductions. The two countries are discussing the historical and potential uses of these incentives to achieve environmental protection at lower costs to society.

Future cooperative efforts related to acidic deposition include:

- Providing up-to-date inventories of total sulphur dioxide and nitrogen oxides emissions.

- Measuring air quality and deposition and refining the predictive capabilities of atmospheric models.

- Recording the chemical and biological improvements in surface waters and responses to changing deposition.

- Determining the role of nitrogen deposition in ecosystem processes and the implications for control of acidification of surface waters.

- Resolving the role of acidic deposition in damage to forests.

- Evaluating human health effects of acidic aerosols and related pollutants.

Much of this work will be carried out jointly or cooperatively by Canadian and American scientists over the next several years. Progress in these and other areas will be reported in the next progress report in 1994.

CONCLUSION

This is the first progress report under the Canada-U.S. Air Quality Agreement. Since the signing of the Agreement in March 1991, the two countries have taken significant steps towards implementing the Agreement. They have formed a bilateral Air Quality Committee and two subcommittees to assist in carrying out the terms of the Agreement. They have initiated, continued, and expanded relationships in a variety of areas related to North American air quality. Most importantly, there has been a free exchange of people and information across their border. While such exchanges occurred prior to the signing of the Air Quality Agreement, the number of contacts and degree of cooperation and exchange of information has increased significantly, to the benefit of both countries. Each Party is pleased with the cooperation the implementation of the Agreement has fostered.

Preface

On March 13, 1991, Canada and the United States signed a bilateral Agreement on Air Quality. The Agreement provides the two countries with a practical and flexible instrument to deal with shared problems of transboundary air pollution. This document is being issued in fulfillment of the provisions in the Agreement that call for a report on progress in its implementation within a year of its entry into force. The next progress report is due in 1994, and reports will follow every two years thereafter.

Canada and the United States share a long tradition of cooperation on environmental matters, most notably on water quality issues under the Boundary Waters Treaty of 1909 and the Great Lakes Water Quality Agreement of 1978, as amended in 1987. The Air Quality Agreement builds on that cooperation. It recognizes that air pollution, like water pollution, respects no international boundaries. The Agreement calls for the establishment of a bilateral air quality committee to oversee and report on its implementation of the Agreement. Annex 1 of the Agreement covers specific programs and objectives and contains targets and timetables for reducing sulphur dioxide and nitrogen oxides, the primary acid rain precursors. This represents a fundamental step in the resolution of a mutual environmental problem. Finally, Annex 2 of the Agreement contains provisions for cooperation on a variety of technical activities related to air pollution.

This report contains information on the Air Quality Agreement itself and initial activities of the Air Quality Committee. The report provides background information on the air pollution programs in both Canada and the United States and discusses progress in implementing the specific objectives in the Agreement. The subject that is at the center of the current obligations and scientific work is acid rain; therefore, the focus of this first report is on our respective acid rain control programs and associated scientific and technical activities. However, the Agreement is a flexible one, such that additional pollutants may be added at a later date upon agreement by the two Parties. Finally, the report addresses the future in terms of what we hope to accomplish both individually and cooperatively under the Agreement.

It is with a shared sense of friendship and commitment to protecting public health and the environment that we embark on this important endeavor.

The United States-Canada
Air Quality Committee

March 1992

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Introduction

On March 13, 1991, Prime Minister Mulroney and President Bush signed a bilateral Air Quality Agreement in Ottawa. The Agreement is composed of a main body and two annexes. The body contains 16 Articles, covering a wide variety of topics including general and specific objectives; assessment, notification, and mitigation; the establishment of a bilateral Air Quality Committee; and procedures for consultations, referrals, and settlement of disputes. Annex 1 contains specific programs and objectives concerning sulphur dioxide and nitrogen oxides, which were designed to address acidic deposition in both countries. Annex 2 relates to scientific and technical activities and economic research. The full text of the Agreement can be found as Appendix B to this report.

HISTORY OF THE AGREEMENT

Canada and the United States share a long tradition of cooperation on economic, political, and environmental issues. The two countries share the longest undefended border in the world and are each other's largest trading partner. Since pollution knows no boundaries, they also share transboundary transport of pollution. For many years, the two countries have worked together on environmental issues, most notably on water quality issues under the Boundary Waters Treaty of 1909 and the Great Lakes Water Quality Agreement of 1978, as amended in 1987.

The seeds for an agreement on air quality were sown in 1978, when Canada and the United States established the Bilateral Research Consultation Group (BRCG) to facilitate information exchange, coordinate research, and develop a scientific data base on acid rain. The BRCG's first report in 1979 showed large areas of North America sensitive to acidic deposition (a term used to incorporate both wet and dry deposition of acidic compounds).

In 1980, Canada and the United States signed a Memorandum of Intent (MOI) Concerning Transboundary Air Pollution. The MOI stated the intention of both nations to develop a bilateral agreement and vigorously enforce existing air pollution legislation. The MOI also established work groups to develop the scientific and technical basis for an agreement. In 1981, formal negotiations began on a bilateral agreement, but these negotiations broke off in 1982. In 1983, the MOI work groups published their reports.

Throughout the 1980s, both countries conducted research and assessment programs on the causes and effects of acidic deposition and on the potential consequences of control actions. In Canada, this work was conducted under the auspices of the federal/provincial Research and Monitoring Coordinating Committee (RMCC). In the United States, the National Acid Precipitation Assessment Program (NAPAP), a legislatively mandated 10-year program created in 1980, was the focal point for acid rain research. The RMCC published "The 1990 Canadian Long-Range Transport of Air Pollutants and Acid Deposition Assessment Report," and NAPAP published the "Integrated Assessment Report" in 1991, as well as 27 State of Science and Technology Reports in 1990 and 1991. The

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STEPS LEADING TO THE AGREEMENT

1980	**U.S. and Canada sign a Memorandum of Intent (MOI) concerning transboundary air pollution**
Throughout the 1980s	**U.S. and Canada conduct extensive research and assessment programs**
1985	**Canada establishes a sulphur dioxide control program in eastern Canada**
1986	**Special Envoys publish report recognizing acid rain as a serious transboundary problem**
1990	**Formal negotiations for an air quality agreement begin in August**
1990	**New Clean Air Act Amendments in U.S. include acid rain control program**
1991	**President Bush and Prime Minister Mulroney sign the Air Quality Agreement on March 13**

RMCC and NAPAP held bilateral annual technical coordination and review meetings throughout most of the 1980s, producing a joint science report in 1987.

In 1985, Canada established a sulphur dioxide control program in eastern Canada that called for a reduction in 1980 emissions by 1994 to a level of 2.3 million tonnes. Canada had earlier committed to cut emissions by at least 30 percent as part of its commitment under the United Nation's Economic Commission for Europe's Convention on Long-Range Transboundary Air Pollution (LRTAP). The United States, meanwhile, continued to control sulphur dioxide emissions as a result of its ambient air quality program under the Clean Air Act and its amendments through 1977, and to carry out research under NAPAP.

During the mid-1980s, dialogue on the acid rain issue continued at the highest levels of government. Prime Minister Mulroney and President Reagan, meeting in 1985, appointed Special Envoys to study the issue of acid rain. The Special Envoys (William Davis of Canada and Drew Lewis of the United States) published their report in early 1986. It recognized acid rain as a serious transboundary problem and called for the United States to embark on a program of technology development and deployment aimed at demonstrating technologies that could reduce emissions of sulphur dioxide and nitrogen oxides from coal-burning electric power plants. The United States subsequently initiated the Clean Coal Technology Program, a 5-year, $5 billion program jointly funded by the public and private sectors. This period also was marked by enhanced U.S. research on the causes and effects of acid rain and by the growing emergence of a consensus on the need to reduce precursor emissions.

The achievement of the present Air Quality Agreement can be traced back to February 10, 1989, when President Bush met with Prime Minister Mulroney in Ottawa. The President committed the United States to negotiate an air quality agreement with Canada in conjunction with his proposal to amend the Clean Air Act. Informal discussions were held between the two governments during 1989 and 1990. Formal negotiations began in August 1990, and concluded in December of the same year, one month after President Bush

signed the Clean Air Act amendments into law in the United States. The Agreement was signed by the two leaders in Ottawa on March 13, 1991.

Thus, the signing of the Agreement was the culmination of over 10 years of discussions on the issue of transboundary air pollution, especially acid rain. The period in between was marked by ongoing research programs, technology development, intermittent attempts at negotiating an agreement on air quality, and the development of acid rain control programs.

Article VIII of the Air Quality Agreement established a bilateral Air Quality Committee to (1) review progress made in the implementation of the Agreement; (2) prepare and submit to the two governments progress reports on the implementation of the agreement; (3) refer each progress report to the International Joint Commission for the solicitation of public comments and preparation of a synthesis of views presented during comments; and (4) release the progress report to the public after its submission to the two governments.

The Air Quality Committee is composed of nine representatives from each government and has two subcommittees to assist in carrying out its work. Subcommittee 1 is responsible for overseeing the implementation of the specific programs and objectives contained in Annex 1 of the Agreement. It is also responsible for related work on emission inventories, control technologies, and market-based mechanisms. Subcommittee 2 provides a forum for discussion on many of the scientific and technical activities, including atmospheric effects research and monitoring, covered in Annex 2 of the Agreement. The membership of the Air Quality Committee, as well as the terms of reference for the committee and two subcommittees, are included in Appendix A to this report.

Initially, the Air Quality Committee focused on achievements in implementing the specific programs and objectives contained in the Agreement, assessing current cooperative endeavors, and discussing areas where cooperation could be initiated or expanded. The Air Quality Committee met for the first time on November 26, 1991, in Washington, DC. That meeting focused on relevant national and bilateral activities and topics to be addressed in this first progress report. The two subcommittees met in November 1991 to discuss topics such as the implementation of respective emission reduction programs and atmospheric deposition and effects research and monitoring.

The Agreement calls for each Party to notify the other of a proposed action, activity, or project likely to cause significant transboundary air pollution, and, as appropriate, to take measures to avoid or mitigate the potential risk posed by such action, activity, or project. Both countries have started to work on the criteria to be used to implement this provision of the Agreement.

The initial focus of the Air Quality Committee has been on achievements in implementing the specific programs and objectives contained in the Agreement, assessing current cooperative endeavors, and discussing areas where cooperation could be initiated or expanded.

Progress: Specific Programs and Objectives

OVERVIEW

In signing the Air Quality Agreement, Canada and the United States committed to specific programs and objectives designed to produce cleaner air and a healthier environment for Canadians and Americans. Annex 1 to the main Agreement sets out the commitments that each country has made to control acid rain precursors: sulphur dioxide (SO_2) and nitrogen oxides (NOx). SO_2 is the primary pollutant involved in the formation of acid rain, or acidic deposition (a more exact term that incorporates both wet and dry deposition of acidic species). NOx also plays an important role in the formation of acidic deposition. It plays a predominant role in certain regions and in certain acidic episodes. The emission reduction programs included in Annex 1 cover both stationary sources (e.g., smelters, electric utility plants, and industrial commercial boilers) for SO_2 and NOx reductions and mobile sources (e.g., motor vehicles) for NOx reductions.

The Annex 1 obligations recognize the different approaches taken by Canada and the United States in their efforts to reduce the effects of acidic deposition.

Canada and the United States control air pollution by using several approaches. Two important approaches will be described here. The first, adopted primarily to protect human health, sets limits for specific pollutants as concentrations in air, e.g., parts per million of air, or micrograms per cubic meter of air. Both countries have air concentration limits for sulphur dioxide and nitrogen oxides, and each has been relatively successful in attaining these air quality limits.

The second approach aims to reduce the total amount of pollutant falling on a given area, and is associated with protecting ecosystems against the negative effects of pollution. Loadings can be expressed as weight of pollutant per unit of land area per unit of time. For example, Canada has a target loading for the eastern part of the country of 20 kilograms of wet sulphate per hectare of land per year. This particular loading was developed in the early 1980s to protect moderately sensitive surface waters against the effects of acidification. In the United States, the Clean Air Act (CAA) as amended in 1990 limits national SO_2 emissions without reference to units of land area. The acid rain control provisions of the CAA are designed to substantially reduce and eventually place a cap on annual emissions of SO_2. These provisions reflect, in part, a desire to reduce deposition to sensitive aquatic resources so that acidification of lakes and streams would be reversed or slowed down.

In concept, "total" loading involves both wet and dry deposition. Due to the lack of information on the dry deposition component, the early development of the total loading concept focused on wet deposition alone. This approach is probably more appropriate for Canada and for regions of the United States where dry deposition rates are low, and less appropriate for areas where

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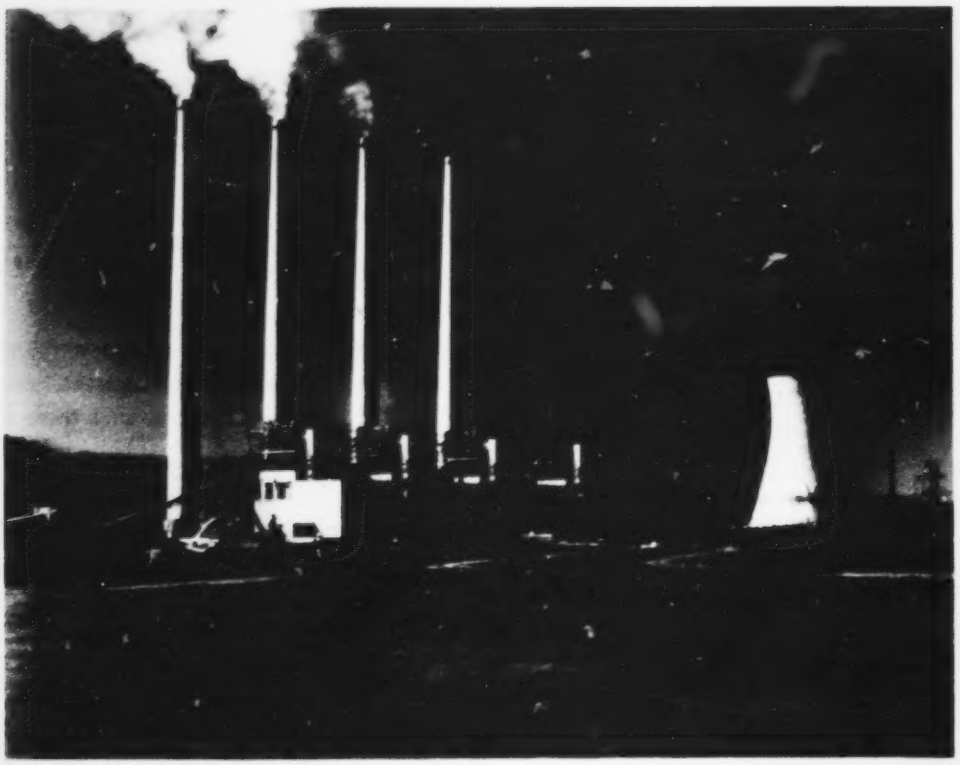


the relative contribution of dry deposition to overall deposition is larger and/or more regionally variable.

Both countries have experienced acidification of surface waters in geographically diverse areas, which led to policies designed to reduce the deposition of sulphur compounds on watersheds. A concern also is shared for the effect of acidic deposition on forests and forest soils, and on materials, and for the potential health threat posed by elevated levels of acidic aerosols in the atmosphere. In the United States, there also has been a great concern about the adverse effect of air concentrations of sulphate particles on visibility in the eastern part of the United States and in national parks and wilderness areas of the west (e.g., Glacier National Park, the Grand Canyon).

In the sections that follow, the obligations of the two governments relating to specific programs and objectives are summarized, and progress toward the fulfillment of those obligations is noted. Areas covered include emission reduction goals, affected sources, timing of reductions, geographic domain, methods used to achieve reductions, and emissions monitoring. In addition, a discussion of "prevention of significant deterioration" and visibility protection in the context of the Air Quality Agreement is included.

SULPHUR DIOXIDE

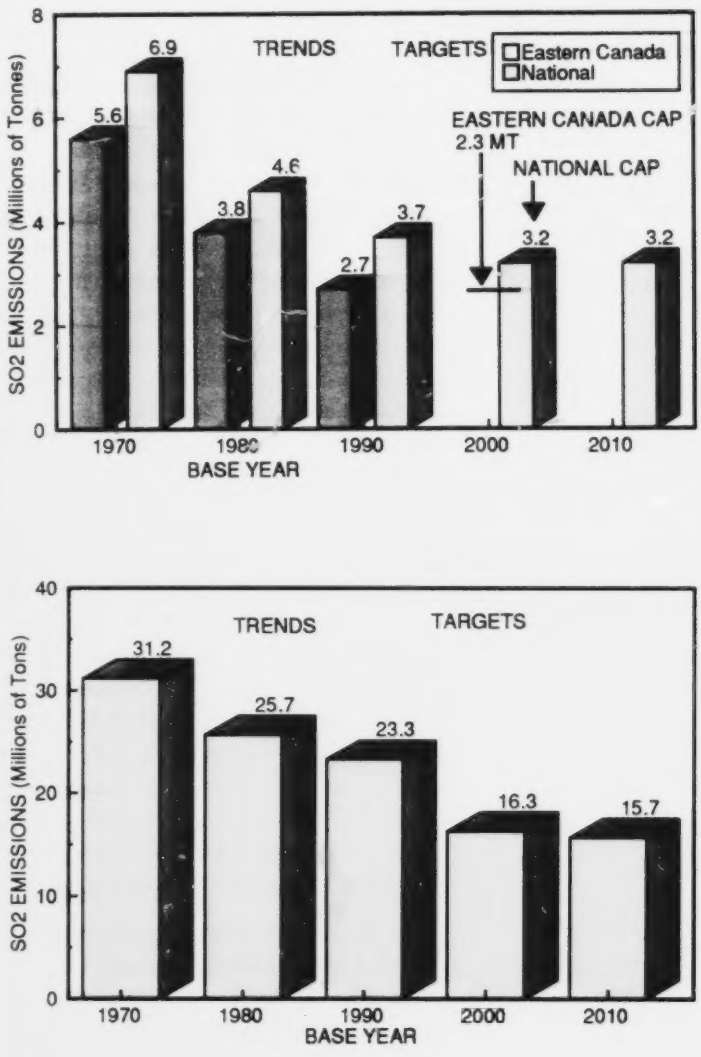
Overview of Obligation/ Emission Reduction Goals

Both countries have undertaken obligations to reduce emissions of sulphur dioxide from stationary sources and to implement caps on those emissions. In this report, short tons ("tons") and metric tons ("tonnes") are used. One ton is equal to 0.9 tonnes. Conversely, one tonne is equal to 1.1 tons. In accordance with Annex 1, Canada is obligated to reduce SO_2 emissions in

the seven easternmost provinces to 2.3 million tonnes per year by 1994, and to maintain an annual cap of 2.3 million tonnes on those emissions through December 31, 1999. Furthermore, Canada is committed to achieving a permanent national cap on SO_2 emissions of 3.2 million tonnes per year by the year 2000. The United States is committed to reducing annual SO_2 emissions by approximately 10 million tons below 1980 levels by the year 2000, with the exception of sources repowering with qualifying clean coal technologies and those receiving bonus allowances in accordance with provisions contained in the CAA. The United States' commitment represents a reduction of approximately 40 percent in SO_2 emissions compared to 1980, the base year used in both Canada and the United States for measuring progress in their respective acid rain control programs. In addition, the United States is committed to achieving a permanent national cap of 8.95 million tons of SO_2 per year for electric utilities by 2010. Finally, the United States is committed to ensuring that industrial emissions of SO_2 do not exceed 5.6 million tons, in accordance with provisions contained in the CAA.

Trends and targets for SO_2 emissions in Canada and the United States are in Figure 1, which illustrates the long-term downward trend in emissions in both countries.

Figure 1



Implementation Overview

Canada

In 1985, the federal government and the governments of the seven easternmost provinces agreed to establish a program to reduce emissions of SO_2.

This program, formalized in federal-provincial agreements signed in 1987 and 1988, established specific targets and timetables for reducing emissions in each province. The federal government undertook to seek reductions in transboundary flows of SO_2 and to support research and development, including demonstrations, of SO_2-reducing technologies.

The Eastern Canada program requires that total annual SO_2 emissions from the provinces east of Saskatchewan be reduced to 2.3 million tonnes by the end of 1994, a decrease of about 40 percent from the 1980 level of 3.8 million tonnes. Each province agreed to a specific overall reduction target and timetable. In essence, a "bubble" has been placed over each province, and the province left to decide how to achieve the reduction needed to stay within the "bubble" or emission cap. The 1980 emission levels and the 1994 targets are contained in Figure 2.

In general, control efforts have been directed at major SO_2 sources, such as non-ferrous metal smelters and fossil fuel burning power plants, where the largest and most cost-effective reductions can be achieved. These sources emitted about 62 and 20 percent, respectively, of Canada's SO_2 emissions in 1985. As a result, six large copper, nickel, and zinc smelters; one iron ore sintering plant; and three provincial electrical utilities are responsible for implementing the major portion of the control program.

In the case of smelters, provinces have established regulated emission levels for each individual smelter. However, electric utilities in most provinces have been allocated a specified share of the provincial cap for 1994, and have been allowed to trade freely among their various power plants and generating units within the province to meet their allocation. The form of control imposed allows these source sectors to choose among the range of potential control options, including such methods as process changes in the case of smelters, fuel switching or energy conservation programs to reduce electricity demand in the case of power plants, or back-end control technologies in either case. Some of the provincial programs also contain controls for other sectors, such as limits on the sulphur content of heavy fuel oil in Ontario and Quebec, and regulated emission limits for pulp mills and refineries in Quebec.

Between 1987 and 1994, the major emitters will invest about $1.7 billion in capital projects to reduce their SO_2 emissions. The average annual investment over the period is $248 million per year, but, during the final four years, the investment in capital projects will be approximately $352 million per year.

Investments in capital projects will continue beyond the end of 1993. For example, Ontario Hydro will continue to invest about $206 million a year in abatement projects from 1994 to the end of 1998 in order to keep emissions below the limit while allowing for growth in electrical generation. Nova Scotia Power will invest another $170 million between 1994 and 2010 for the same reason.

Since the signing of the Air Quality Agreement in 1991, considerable progress has been made towards meeting the 2.3 million tonne target for 1994. During the past year, remedial measures to reduce emissions from existing SO_2 sources in eastern Canada included:

- Awarding of contracts for wet limestone scrubbers for two of the four 500 MWe generating units at the Lambton power plant in Ontario.
- Release of a revised supply/demand plan by Ontario Hydro, which features increased reliance on existing facilities and, linked to their life extension, the possible retrofit of up to

10 units with flue gas desulphurization (FGD, or "scrubbers").

- Commencement of operation of a new ore processing mill at the Inco smelter at Sudbury, Ontario, to remove concentrated sulphur (phyrrhotite) from the ore before it enters the smelter, and the completion of the first of two flash furnaces that will allow much higher recovery of SO2 in the smelter's acid plant.

- Completion of major changes in 1990 to the smelting process at the Noranda, Quebec, smelter that substantially increase the efficiency of sulphur capture at the new acid plant installed in 1989.

- Enactment of a sulphur in fuel oil limit of 1.5 percent for the power plant at Tracy, Quebec, and 2.0 percent for existing industrial boilers in Quebec.

- Acceleration of demand management and efficiency programs by Canadian electric utilities to forestall the need for new generating capacity and to reduce fossil fuel consumption.

- Beginning of a $187 million project to modernize Hudson Bay Mining and Smelting's Flin Flon, Manitoba, smelter. As part of the project, there will be a replacement of the current zinc plant by a zinc pressure leach plant. This will reduce SO_2 emissions by 25 percent, from 293,000 to 220,000 tonnes, allowing Manitoba to meet its new emission limit by 1994.

SO_2 EMISSION REDUCTION GOALS

Canada

- SO_2 emissions reduction in 7 easternmost provinces to 2.3 million tonnes by 1994
- Maintenance of 2.3 million tonne annual cap through December 1999
- Permanent national annual cap on SO_2 emissions of 3.2 million tonnes by the year 2000

United States

- SO_2 emissions reduction by 10 million tons from 1980 levels by the year 2000
- Permanent national cap of 8.95 million tons for electric utilities by the year 2010
- Cap of 5.6 million tons for industrial source emissions

- Decision to convert the 315 MWe Dalhousie power plant in New Brunswick to an orimulsion fuel and install a scrubber.

At new sources in Eastern Canada, measures are being taken to minimize additional SO_2 emissions and to ensure that provincial caps are not exceeded. During the past year:

- Tenders were awarded for an SO_2 scrubber at the 450 MWe coal-fired Belledune power plant under construction in northern New Brunswick.

- A 1.5 percent sulphur content limit for heavy fuel oil was enacted in Quebec for all new industrial boilers.

- Construction proceeded on the 165 MWe fluidized bed power plant at

TABLE 1. Annual SO_2 Emissions and Targets for Eastern Canada (kilotonnes)

	EMISSIONS			TARGETS
	1980[1]	1985[1]	1990[1]	1994
Newfoundland				
Power Generation	18	22	23	—
Total	56	43	47	45
Prince Edward Island				
Power Generation	2	—	2	—
Total	5	3	3	5
Nova Scotia				
Power Generation	125	130	143	—
Total	193	170	178	204
New Brunswick				
Primary Metals[3]	13	17	8	—
Power Generation	122	94	141	—
Total	220	138	187	185
Quebec				
Primary Metals	641	483	189	—
Total	1,098	693	396	600[4]
Ontario				
Primary Metals[3]	1,031	899	730	—
Power Generation	398	337	195	—
Total	1,764	1,457	1,250	885
Manitoba				
Primary Metals[3]	463	459	489	—
Total	484	469	505	550
Eastern Canada				
Primary Metals[3]	2,148	1,858	1,416	—
Power Generation	665	583	504	—
Other	1,007	532	646	—
Total	3,820	2,973	2,566	2,474[2]

Notes:

1 Numbers for 1980 and 1985 are taken from Environment Canada Report RPS 5/AP/3, March 1990. Estimates for 1990 are preliminary numbers based on submissions from provinces.

2 The 1994 Eastern Canada limit is 2,300 kilotonnes. The current total of agreed-to objectives is 2,474 kilotonnes; the remaining 174 kilotonnes is expected to be allocated sometime in 1992 through amendment of the current federal/provincial agreements.

3 Primary metal includes non-ferrous smelters and iron ore beneficiation but excludes aluminum production.

4 The target for Quebec of 600 kilotonnes is for the year 1990; the province opted to complete its reduction program in 1990 rather than in 1994.

Point Aconi, Nova Scotia, which will have 90 percent SO_2 removal capacity and NOx emissions at least 30 percent below current new source standards.

The 1990 data on Canadian SO_2 emissions indicate that emissions in Eastern Canada are now within about 16 percent of the program target of 2.3 million tonnes by 1994.

A new program that will aim at allowing Canada to maintain a national cap of 3.2 million tonnes by December 31, 1999, is being developed. Reductions currently occurring under the Eastern Canada program also are contributing to a decline in SO_2 emissions nationally towards the 3.2 million tonne level. Emissions nationally in Canada were 4.6 million tonnes in 1980 and by 1990 had declined to 3.5 million tonnes, or nearly 80 percent of the reduction needed to reach the 3.2 million tonne target. More information on the national program should be available for the next progress report.

United States

The U.S. SO_2 emission reductions will be implemented primarily through the use of an innovative system of SO_2 emission allowances. Each allowance permits its holder to emit one ton of SO_2 during or after a given year. Allowances will be allocated to affected utility units based on their historic fuel use and emission rates specified in the CAA amendments. Once allocated, allowances are fully marketable. They can be sold to other parties or banked for future use. The primary requirement of the acid rain program is that sources hold a sufficient number of allowances at the end of the year to cover their annual emissions. At the end of the year, emissions data will be compared to emission allowance holdings to determine compliance. If a unit fails to hold a sufficient number of allowances to cover its emissions, it must pay an excess emissions fee of $2,000/ton for every ton in excess of the allowances held. In addition, the noncomplying unit would have to forfeit allowances from the next year's allocation to offset the excess emissions.

Affected Sources, Timing, and Cost of Reductions

The U.S. SO_2 emission reductions will be implemented in two phases, which will entail a tightening of the restrictions placed on fossil fuel-fired electric generating plants. The first phase commences January 1, 1995, and the second phase commences January 1, 2000. In the first phase, 261 units at 110 electric utility plants in 21 eastern states will be affected. These sources will be allocated the number of allowances specified in the CAA. The allocations were calculated on the basis of each unit emitting at 2.5 pounds SO_2 per million British Thermal Units (BTUs) heat input. At the end of 1995 and each year thereafter, these Phase I units must hold a sufficient number of allowances to cover their annual emissions.

In Phase II, approximately 2,500 electric generating units serving generators with capacities of 25 megawatts or greater (including those covered under Phase I) will be allocated allowances based on a series of formulas contained in the legislation. This allocation will result in a substantial reduction in allowable utility emissions of SO_2. In 2010, when the program is fully implemented, the annual allocation of allowances

will result in a national emission cap on utility units of 8.95 million tons. Under the acid rain program, new utility units, including those smaller than 25 megawatts, will not be allocated emission allowances but will be required to obtain allowances from others to cover their emissions.

The market-based allowance system has been estimated to reduce costs of compliance with acid rain control provisions by approximately 20 percent compared to traditional "command and control" approaches. The costs of the acid rain control program in the United States have been estimated at approximately $1 billion a year in Phase I and approximately $4 billion a year in Phase II. Therefore, the potential cost savings from using a market-based system are significant. The market-based approach was given added support in 1991 when the Chicago Board of Trade announced its intention to establish a futures market in emission allowances.

Geographic Domain of Control/Deposition Patterns

The United States acid rain control program applies to the 48 contiguous states and the District of Columbia (Hawaii and Alaska are not covered). All sources that meet defined criteria will be subject to the requirements articulated in Title IV of the CAA. As noted above, the sources affected in Phase I that will have to undergo emission reductions starting in 1995 are all located in the eastern part of the country where most older, higher emitting plants are located. The states with the largest number of affected units and required emission reductions are Ohio, Indiana, Illinois, Pennsylvania, and West Virginia. Early indications suggest that some sources in these states will choose to control beyond the requirements of the legislation, and will sell their excess allowances to units in their own or other states where the cost effectiveness of emission reductions is lower.

Analyses conducted under the auspices of NAPAP suggest that emissions trading, which is designed to increase economic efficiency in achieving emission reductions, would not lead to broad regional differences in deposition patterns compared to an approach that would not allow trading. One of the practical reasons for this is that emissions of sulphur dioxide in the United States are heavily concentrated in the midwestern part of the country, and switching emission reductions among sources would not result in dramatic changes over thousands of square miles in the United States and Canada. Once the emission reduction program in the United States is implemented and actual trading has taken place, the United States will conduct analyses of the economic and environmental consequences of trading.

Compliance Methods

Under the U.S. acid rain control program, a source can decrease its emissions to meet the number of allowances it holds, increase the number of allowances it holds up to the level of its legal level of emissions, or combine these two options. If a source chooses to reduce its emissions to meet the number of allowances it holds, it has several options available to it. These include employing energy conservation measures, increasing reliance on renewable energy, reducing utilization, employing pollution control technologies, or switching to lower sulphur fuel. If a source chooses to increase its allowance holdings to the level of its emissions, it can transfer them from

another unit in its system that has an excess; buy allowances from a broker or from another utility that may have exceeded its control requirements (thus having allowances available to sell); buy allowances from an industrial plant or unaffected utility that elects to opt into the allowance system; or, buy allowances through a legislatively required EPA-sponsored allowance auction and sale program. The method(s) that any individual source selects to comply with the requirements of the law will be determined by the source. While the government will eventually evaluate the impact of compliance decisions, it will not dictate which compliance measures sources must select.

Since Phase I of the acid rain control program does not require emission reductions until 1995, it is too early to report on actual compliance decisions. However, it is apparent that a significant number of utilities are making plans to install scrubbers to comply with Phase I reduction requirements. A good deal of specific information on Phase I reduction decisions is likely to be available by the time the next progress report is published in 1994.

Progress in Implementing Sulphur Dioxide Obligations

The past year has been an active one in terms of implementing the acid rain control provisions of the CAA and the requirements of Annex 1 of the Air Quality Agreement. Under the U.S. system, Congress sets out the requirements of the program, and the executive branch of government is responsible for developing and promulgating the regulations that define how the law will be implemented. The executive branch has the responsibility to promulgate regulations implementing the acid rain control program. In December 1991, EPA promulgated final rules on the auction and direct sale of allowances and proposed rules in four areas of critical importance to the acid rain program: sulphur dioxide allowances, acid rain permits, continuous emission monitoring, and excess emissions.

Future regulations include the allowance allocation rule, which sets forth the initial allocation of allowances that each utility unit will receive and the "opt-in" rule, under which industrial sources will be given an opportunity to opt-in to the allowance system. These rules are all subject to public review and comment periods within the United States, and most are expected to be finalized by the end of 1992. By the next Air Quality Agreement progress report, there will be significant movement toward Phase I compliance. For example, by February 1993, all Phase I sources will be required to submit permit applications and compliance plans, making it much clearer how Phase I units intend to comply with their emission limits. Additionally, all Phase I units will have to install continuous emission monitors by the end of 1993.

NITROGEN OXIDES

Canada

Under Annex 1 of the Air Quality Agreement, Canada committed to reduce its nitrogen oxides (NOx) emissions from stationary sources by 100,000 tonnes from a forecast emission level of 970,000 tonnes in the year 2000. In addition, Canada is committed to implementation of more stringent NOx emission standards for

light, medium, and heavy duty vehicles through the period 1996 to 1998.

Canadian NOx emissions were 1.9 million tonnes in 1985, with 63 percent originating from mobile sources, mainly light and heavy duty vehicles and off-road diesel equipment. Major stationary sources include power plants, boilers and heaters, pipeline compressors, and gas turbines. If no further controls other than those already in place are implemented, it is estimated that by 2000, NOx emissions from stationary sources will rise to 970,000 tonnes from a level of 707,000 tonnes in 1985, and those from mobile sources will drop to 960,000 tonnes from a level of 1.18 million tonnes in 1985.

Emission reductions will be achieved through the implementation of the Management Plan for Nitrogen Oxides (NOx) and Volatile Organic Compounds (VOCs). The federal-provincial plan was developed by the Canadian Council of Ministers of the Environment and adopted in principle in November 1990.

The NOx/VOC Management Plan is directed specifically at reducing the exposure of Canadians and the Canadian environment to excessive concentrations of ground-level ozone. The plan also is intended to ensure that Canada meets its international obligations for NOx controls. These are found in the United Nations Economic Commission for Europe NOx Protocol of 1988 (under the Convention on LRTAP) and the Canada-United States Air Quality Agreement of 1991. It must be noted that because ground-level ozone is regional in nature, national NOx emission reduction targets were not viewed as appropriate control criteria. Consequently, there are no national emission reduction targets set out in the NOx/VOC Management Plan.

Measures identified in the NOx/VOC Management Plan for mobile sources include a more stringent standard of 0.4 grams per mile (gpm) of NOx for cars and trucks by 1994, a 5 g/BHP-hr standard for heavy duty trucks (already in place on a voluntary basis) by 1994 and tighter standards of 4 g/BHP-hr by 1998, standards for off-road diesel equipment, and a cap on NOx emissions from rail transport. Regarding the more stringent NOx standard for passenger cars, Transport Canada announced on February 20, 1992, a formal agreement with major automobile manufacturers on voluntary compliance with standards equivalent to those in the United States for 1994 and 1995, pending introduction of a regulation under the Motor Vehicle Safety Act for the 1996 model year.

Control measures proposed for new stationary sources include more stringent NOx emission limits for power plants, tur-

bines, industrial-commercial boilers and heaters, and large stationary reciprocating engines. In addition, provinces are developing remedial NOx reduction programs for major existing stationary NOx sources in ozone non-attainment areas. These sources include power plants, commercial iron and steel mills, and refineries.

The NOx reduction program is now being formalized in federal-provincial agreements that will allocate responsibility for achieving emission reductions and for monitoring and reporting of results.

It is expected that reduction of NOx emissions nationally from all sources will amount to about 175,000 tonnes by the year 2000. This represents a 7.2 percent reduction from the 1985 emission level. Reductions in key source areas that have the greatest effect on acidification will be greater than the national average.

A second phase of the NOx/VOC Management Plan will be developed by 1995. More NOx emission reductions are likely to be required in this second phase and will form the basis for the program to meet the commitment in the Air Quality Agreement for further annual national emission reduction requirements from stationary sources to be achieved by 2000 and/or 2005.

United States

Under Annex 1 of the Air Quality Agreement, the United States is obligated to implement a NOx control program with a view to a reduction of total annual emissions of NOx of approximately 2 million tons from 1980 levels of 21 million tons. The emission reductions will come from both stationary sources (electric utility plants) and mobile sources (motor vehicles), and will be achieved by setting new emission limits for these sources. Unlike the emission limits for SO_2, which are defined in terms of total tons, the emission limits for NOx are set in a more traditional manner. For electric utility boilers, the limits are set as pounds of NOx per million BTUs, while for automobiles, they are set as grams of NOx per mile; unlike the SO_2 control program, there are no tonnage limits on the amount of NOx that can be emitted. In the absence of new controls, the NOx emissions from electric utility plants were projected to be approximately 2 million tons higher in the year 2000 than they were in 1980. Mobile sources are projected to experience a real decline in emissions by the year 2000 compared to 1980, such that the actual emission reductions from all sources are likely to be well over 2 million tons.

The NOx control provisions in the United States are specified in both Title II (mobile sources) and Title IV (acid deposition control) of the CAA; parallel requirements are spelled out in Annex 1 of the Air Quality Agreement. Substantial NOx control also is expected under Title I of the CAA, but the magnitude and location of these reductions is subject to future state and federal discussions.

Under the mobile source provisions, the gpm for NOx limits will be phased-in starting with the 1994 model year for light duty vehicles and some light duty trucks, and will be fully implemented by the 1996 model year for light duty vehicles and the 1997 model year for light duty trucks. The NOx limits for heavy duty trucks will be phased-in beginning in 1991 and will be fully implemented by 1998. The standard will be 0.4 gpm for light duty vehicles

(which includes passenger cars). The standard for cars represents about a 60 percent decrease from the current standard.

Regulations implementing this provision of the CAA were promulgated in June 1991. In addition, the useful life of pollution control equipment has been extended from 50,000 miles to 100,000 miles. Congress, in the law, also required EPA to make a determination by the end of 1999 whether or not there is a need to further reduce NOx emissions from vehicles (i.e., to go down to 0.2 gpm from 0.4 gpm). The NOx control provisions will affect all automobiles sold in the United States, with some areas (e.g., California) adopting even stricter standards.

Under the U.S. acid rain control program, the new standards must be set for different classes of boilers used in the production of electricity. These requirements also will be implemented in two phases. EPA will establish Phase I emission limitations to be met by two types of boilers by 1995. Subsequent regulations for affected units not subject to the Phase I NOx limits will be met in Phase II. The rules to implement the Phase I NOx requirements currently are being developed.

COMPLIANCE MONITORING

In Annex 1 of the Air Quality Agreement, Canada and the United States undertook certain obligations regarding the monitoring of emissions from electric utility units and other major stationary sources. For all new electric utility units and existing units greater than 25 MWe, Canada is required to estimate emissions of SO_2 and NOx using a method comparable in effectiveness to continuous emission monitors and to investigate the feasibility of using continuous emission monitoring systems. Continuous emission monitoring (CEM) is the measurement on a continuous basis of pollutants emitted into the atmosphere in exhaust gases from combustion processes or as by-products of industrial processes. This requirement becomes effective January 1, 1995. For the United States, the requirement is that, by January 1, 1995, each new electric utility unit and each electric utility unit greater than 25 MWe that existed at the time of the signing of the CAA amendments (November 15, 1990) emitting SO_2 or NOx install and operate continuous emission monitoring systems or alternative systems approved by the Administrator of EPA, to the extent required by section 412 of the CAA. The Parties agreed to consult, as appropriate, concerning the implementation of these requirements. For other major stationary sources, such as smelters and industrial boilers, Canada and the United States have agreed to work toward utilizing comparably effective methods of emission estimation for SO_2 and NOx.

Canada

SO_2 and NOx emissions are being continuously monitored at several Canadian power plants, although the majority of plants are not yet being monitored. The 1981 Federal Thermal Power Generation Emissions—National Guidelines for New Stationary Sources recommends that a continuous monitoring system for SO_2 and NOx be installed on each new source.

The current revision of this national standard, being prepared as part of the NOx/VOC Management Plan, will include a requirement for continuous NOx emission monitoring at new power plants.

Some provinces (e.g., Saskatchewan) have programs to install continuous emission monitors on their existing power plants.

Canada will be further evaluating actions required to fulfill its commitments under the Agreement and will report in more detail on its SO_2 and NOx compliance monitoring programs in the second progress report. The United States is sharing information with Canada on the implementation of the CEM requirements of the CAA in order to assist Canada in its evaluation.

United States

In December 1991, EPA proposed a CEM rule as part of its overall implementation of the acid rain control provisions of the CAA as amended in 1990. Equipment required by the proposed rule must be installed, certified, and operational by November 15, 1993, for Phase I affected units, and by January 1, 1995, for Phase II units. CEMs are an important component of the SO_2 market-based allowance system that will be utilized, helping to ensure that complete and accurate emissions data are available.

Under the proposed rule, the owner or operator of a unit regulated under Phase I or Phase II (or a unit that opts-in to the program) and any new unit must install a CEM system on the unit unless otherwise specified in the regulation. A CEM system generally might include:

- a sulphur dioxide pollutant concentration monitor;
- a nitrogen oxides pollutant concentration monitor;
- a volumetric flow monitor;
- an opacity monitor;
- a diluent gas monitor; and
- a data acquisition and handling system (computer-based) for recording and performing calculations with the data.

Regarding the methods used to estimate emissions from major stationary sources other than electric utility units, Canada and the United States work together on these issues as part of their joint work on emission inventories. In general, it can be said that the two countries' approaches to estimating emissions from these sources are both compatible and comparable. Work continues on refining these methods. These types of emissions are important, because, for example, non-utility source emissions of sulphur dioxide represent approximately 70 percent of total sulphur dioxide emissions in Canada, and 25 percent of total sulphur dioxide emissions in the United States.

PREVENTION OF SIGNIFICANT DETERIORATION AND VISIBILITY PROTECTION

Annex 1 of the Air Quality Agreement contains provisions on prevention of significant deterioration (PSD) and visibility protection with respect to sources that could cause significant transboundary air pollution. Canada is obligated to develop programs by January 1, 1995, while the United States is obligated to continue its PSD and visibility protection programs relative to transboundary effects to the extent required by the CAA.

Subcommittee 1 of the bilateral Air Quality Committee is responsible for providing a forum for discussion on issues

relative to the implementation of the Agreement's provisions on PSD and visibility protection. The United States is sharing information with Canada on the development and implementation of these programs in the United States as a means of helping Canada in the development of its own PSD and visibility protection programs.

In this section, a brief description of the PSD and visibility programs in the United States is presented. For analyses of historical and present visibility conditions in the United States and expected changes resulting from changes in sulphate concentrations, please refer to the NAPAP State of Science Report No. 24 and the 1990 Integrated Assessment.

Prevention of Significant Deterioration

The U.S. PSD program was designed to keep air in areas with clean air clean. The basic goals of the PSD program are (1) to ensure that economic growth will occur in harmony with the preservation of existing clean air resources; (2) to protect the public health and welfare from any adverse effect that might occur even at air pollution levels lower than the National Ambient Air Quality Standards (NAAQS); and (3) to preserve, protect, and enhance the air quality in areas of special natural recreational, scenic, or historic value, such as national parks and wilderness areas (called "Class I areas"). The primary provisions of the PSD regulations require that major new stationary sources and major modifications to existing sources be carefully reviewed prior to construction to ensure compliance with the NAAQS, the applicable PSD air quality increments, and the requirement to apply the best available control technology (BACT) to minimize the projects' emissions of air pollutants.

No new major source or major modification subject to PSD review may be constructed without a permit. To obtain a PSD permit an applicant must (1) apply BACT; (2) conduct an ambient air quality analysis; (3) analyze impacts to soils, vegetation, and visibility; (4) not adversely impact a Class I area; and (5) undergo an adequate public review process.

Briefly, a "major stationary source" is any source belonging to a list of 28 source categories which emits or has the potential to emit 100 tons per year or more of any pollutant subject to regulation under the Act (both sulphur dioxide and nitrogen oxides are covered), or any other source which emits or has the potential to emit such pollutants in amounts equal to or greater than 250 tons per year.

A "major modification" is generally a physical change or a change in the method of operation of a major stationary source which would result in a "significant" net increase in the emissions of any regulated pollutant. The quantity of net emission increase that qualifies as "significant" varies by pollutant but generally is about 40 tons per year.

Visibility Protection Program

Sulphur dioxide is the primary pollutant associated with visibility degradation. Sulphate particles are responsible for over 50 percent of visibility degradation in the eastern part of the United States, and are important in the western part of the country, which has a large number of national parks and wilderness areas.

In 1977, Congress amended the CAA by adding section 169A, which charged EPA with developing regulations to protect visibility in certain national parks and wilderness areas. "Mandatory Class I Federal areas" are certain national parks, wilderness areas, and international parks. Congress, at that time, set forth a national goal of preventing any future and remedying any existing visibility impairment in those areas caused by manmade pollution. It is known that fine particulate matter, either emitted directly by manmade and natural sources or formed in the atmosphere by reactions of gaseous precursors, is the major cause of visibility impairment.

In 1979, EPA identified 156 mandatory Class I areas where visibility was determined to be an important air quality-related value. In December 1980, EPA promulgated visibility regulations to assure progress toward meeting the national goal. The regulations promulgated by EPA address visibility impairment that can be traced to a single source or a small group of sources.

A visibility monitoring program was established which tracks atmospheric light extinction levels along with fine particle pollution levels in many parks and wilderness areas. EPA works cooperatively with the other federal agencies that administer the parks and wilderness areas (e.g., the National Park Service and the Forest Service) in establishing monitoring programs and reviewing visibility data on impairment. EPA also is planning to track improvements in visual air quality expected from the implementation of the program to reduce acid deposition in the East. This effort will cover areas outside of the national park and wilderness system.

EPA also is conducting research on regional transport of pollution which affects visual air quality. The large regional reductions in SO_2 emissions were achieved under the acid rain control provisions of the CAA that were enacted, in part, to reduce sulphate-based visibility impairment. EPA will continue to develop techniques to analyze regional transport of visibility-impairing pollutants. Under the CAA, the Grand Canyon Commission, consisting of seven western states, was formed to study regional transport in the desert southwest and make program recommendations to EPA regarding visibility protection.

Progress: Scientific and Technical Activities and Economic Research

OVERVIEW

In Annex 2 of the Air Quality Agreement, Canada and the United States have agreed to coordinate certain activities and to cooperate on others. Specifically, they have agreed to coordinate monitoring networks and emission inventory activities and to cooperate on effects monitoring, effects research, atmospheric modeling, control technologies, and analyses of market-based mechanisms to achieve environmental goals. The two Parties have agreed that, initially, the primary focus of these activities will be on acidic deposition and its precursors.

Both countries have had active programs in most of these technical and scientific areas over the past decade. Given the importance of acid rain as both a domestic and bilateral issue, both countries conducted extensive research programs in the 1980s on the causes and the effects of acidic deposition. As noted earlier, in Canada this program was coordinated by the federal/provincial Research and Monitoring Coordinating Committee (RMCC). The RMCC was composed of Environment Canada and the 10 provincial ministries of the Environment. In 1990, the RMCC published its summary analyses in an eight-volume report titled, "The 1990 Canadian Long-Range Transport of Air Pollutants and Acid Deposition Assessment Report." The report includes an executive summary and volumes on emissions and controls, atmospheric science, aquatic effects, terrestrial effects, human health effects, socio-economic studies, and quality assurance.

In the United States, the focal point for acid rain research was NAPAP, a federal interagency effort that included EPA; the National Oceanic and Atmospheric Administration; the Council on Environmental Quality; and the Departments of Energy, Agriculture, and Interior. NAPAP spent 10 years and over $500 million studying the causes and the effects of acid rain and examining the potential effects of various control strategies. In 1990, NAPAP produced 27 State of Science and Technology Reports and an Integrated Assessment. The effects categories examined included aquatic, terrestrial (forests and crops), materials, visibility, and human health; other areas included emissions monitoring and projections; atmospheric processes, modeling and deposition; control technologies; and economic and valuation analyses. NAPAP was reauthorized under the CAA amendments of 1990 to coordinate monitoring activities, identify research gaps, and report on the status and effectiveness of the acid deposition control program. NAPAP must periodically report its findings to the President and Congress.

Canada and the United States both conduct a wide variety of scientific and technical activities related to acidic deposi-

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During the past year, the two countries have met to discuss a variety of topics related to emission inventories, including the production of a 1990 inventory, integration of Canadian and U.S. emission data and projections of future emissions.

tion. For example, emission inventories are developed, atmospheric models are used to plot deposition and air concentration maps, deposition and air concentration monitoring sites are maintained, the mechanisms of pollutants acting on the environment are studied in the laboratory and in the field, and there is monitoring of the effects on the environment (e.g., surface water sampling). This report contains some key information and highlights in all of these areas, in addition to the development of pollution reduction technologies and the use of market-based incentives. More detailed, in-depth information on most of these topics can be found in the publications of the RMCC and NAPAP.

Throughout this report, the terms "acid rain" and "acidic deposition" are both used. "Acid rain" is a simple term that has been used for many years and gained widespread public recognition. The science of acidification processes is more complex than the term "acid rain" implies. The problem of acidification goes beyond the acidity of rain; it also includes the acidifying effects of chemicals that are in the air or involved in deposition to the earth's surface when it is not raining. "Acidic deposition" incorporates both wet and dry conditions. While many chemicals are involved in acidic deposition, it is the sulphur and nitrogen compounds of the overall deposition problem that are central to most of the scientific questions that arise, and are therefore the focus of this report.

EMISSION INVENTORIES

In Annex 2 of the Air Quality Agreement, Canada and the United States agreed to coordinate emission inventory activities for the purpose of ". . .determining and reporting air emissions levels, historical trends, and projections with respect to the achievement of the general and specific objectives set forth in [the] Agreement. . .". In Annex 2, the two Parties also agreed to the use of measurement and estimation procedures of comparable effectiveness and to the use of compatible data management procedures, formats, and methods.

Emission inventories are estimates of emissions of various pollutants that are used for air quality management purposes. National emission inventories are collected for a number of pollutants, including sulphur dioxide and nitrogen oxides. Emissions of pollutants are usually broken down by amount from different source categories, including stationary sources (e.g., electric power plants, smelters, factories), mobile sources (e.g., cars and trucks), and natural sources (e.g., volcanoes, vegetation). Emission inventories are calculated by a variety of methods, including mass balance, data from monitors, and the application of emission factors to various sources. The development of emission inventories is an evolutionary process, with constant development of new methods and enhancement of older ones. For example, the U.S. program to install continuous emission monitors on all the units affected by the acid rain control provisions of the CAA will provide a high degree of precision to a substantial portion of the United States' sulphur dioxide and nitrogen oxides emissions inventories.

Canada and the United States have worked together to produce emission inventories before and are continuing to work together. The most significant cooperation to date occurred during the

compilation of the 1985 inventory developed under the auspices of NAPAP. The NAPAP Inventory contained information on both Canadian and U.S. emissions for a variety of pollutants, including sulphur dioxide and nitrogen oxides. During the past year, the two countries have met to discuss a variety of topics related to emission inventories, including the production of a 1990 inventory, integration of Canadian and U.S. emission data in the U.S. Air Information Retrieval System (AIRS), and projections of future emissions. They have agreed to meet every six months on a continuing basis to carry out their work pursuant to the Agreement.

Canadian and U.S. SO_2 and NOx emissions data for the years 1980 and 1985 and preliminary estimates for 1990 are included in Tables 2 and 3.

ATMOSPHERIC MODELING

In Annex 2 of the Air Quality Agreement, Canada and the United States agreed to exchange information with respect to their development and refinement of atmospheric models for purposes of determining source-receptor relationships and transboundary transport and deposition of air pollutants. In this report, results from linear (Lagrangian) and complex

TABLE 2. Canada/U.S. SO_2 Emission Estimates (10^6 tonnes/ tons/year)

	1980		1985		1990[1]	
CANADA	Millions of tonnes	Millions of tons	Millions of tonnes	Millions of tons	Millions of tonnes	Millions of tons
Utility	0.8	0.9	0.7	0.8	0.8	0.9
Industrial	3.6	4.0	2.8	3.1	2.8	3.1
Other	0.3	0.3	0.2	0.2	0.1	0.1
Total	**4.7**	**5.2**	**3.7**	**4.1**	**3.7**	**4.1**

	1980		1985		1990[1]	
UNITED STATES	Millions of tonnes	Millions of tons	Millions of tonnes	Millions of tons	Millions of tonnes	Millions of tons
Utility	15.5	17.0	14.2	15.6	14.2	15.6
Industrial	6.2	6.8	5.4	5.9	5.4	5.9
Other	1.7	1.9	1.5	1.7	1.6	1.8
Total	**23.4**	**25.7**	**23.1**	**23.2**	**21.2**	**23.3**

1 - Preliminary.

References:

U.S. Data - National Air Pollutant Emission Estimates, 1940-1990 (EPA-450/4-91-02, November 1991).

Canadian Data - Development of the 1980 NAPAP Emissions Inventory (EPA/600/7-86/-57a, December 1986).

The 1985 NAPAP Emissions Inventory (Version 2): Development of the Annual Data and Modelers Tapes (EPA-600/7-89-012a, November 1989).

TABLE 3. Annual NOx Emission Estimates for Canada and the United States (10^6 tonnes/ tons/year

	1980		1985		1990[1]	
CANADA	Millions of tonnes	Millions of tons	Millions of tonnes	Millions of tons	Millions of tonnes	Millions of tons
Utility	0.2	0.2	0.3	0.3	0.3	0.3
Industrial	0.4	0.4	0.4	0.4	0.4	0.4
Mobile[2]	0.6	0.7	0.8	0.9	0.7	0.8
Other	0.6	0.7	0.4	0.5	0.5	0.6
Total	**1.8**	**2.0**	**1.9**	**2.1**	**1.9**	**2.1**

	1980		1985		1990[1]	
UNITED STATES	Millions of tonnes	Millions of tons	Millions of tonnes	Millions of tons	Millions of tonnes	Millions of tons
Utility	6.4	7.0	6.7	7.4	7.3	8.0
Industrial	3.8	4.2	3.4	3.7	3.9	4.3
Mobile[2]	7.9	8.7	7.0	7.7	5.6	6.2
Other	2.8	3.1	2.8	3.1	2.8	3.1
Total	**20.9**	**23.0**	**19.9**	**21.9**	**19.6**	**21.6**

1 - Preliminary.

2 - Mobile - The United States has only highway vehicles - other transportation categories are included under other; Canada has all transportation categories included under mobile.

References:

U.S. Data - National Air Pollutant Emission Estimates, 1940-1990 (EPA-450/4-91-02, November 1991).

Canadian Data - Development of the 1980 NAPAP Emissions Inventory (EPA/600/7-86/-57a. December 1986).

The 1985 NAPAP Emissions Inventory (Version 2): Development of the Annual Data and Modelers Tapes (EPA-600/7-89-012a, November 1989).

non-linear (Eulerian) models used in the assessment of acidic deposition and progress in the evaluation of Eulerian models are presented.

In the sections that follow, the following are discussed: atmospheric model application, atmospheric model evaluation, and atmospheric model development.

Atmospheric Model Application

Canada and the United States have developed strong acid deposition modeling programs over the past several years and are in a good position to meet the objectives of the Air Quality Agreement.

Models are used to characterize regional source-receptor relationships, including those of the transboundary transport of pollutants. Efforts are under way to exchange information on the use of atmospheric models to augment monitoring data. The augmentation of data also is intended to help provide more timely estimates of atmospheric deposition and air quality for the assessment of current and estimation of future ecological effects. Information also is

being exchanged regarding the use of atmospheric models to anticipate trends in air and precipitation concentrations that would be expected in the annual and seasonal time series from the monitoring data.

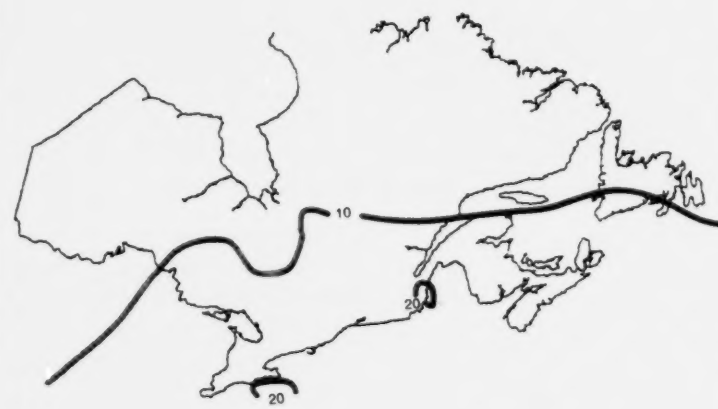
Atmospheric models have played an important role in assessment and application studies in both countries. A major assessment effort by Canada was completed in 1990; the results were published in the "1990 Canadian Long-Range Transport of Air Pollutants and Acid Deposition Assessment" report. Canadian estimates of current and future wet sulphate deposition, assuming full U.S. and Canadian control programs, are shown in Figure 2. The Canadian analysis, which was based on the Ontario Ministry of the Environment's long-range transport model, shows that, when the control programs in both countries are fully implemented, wet sulphate deposition for the most part will be less than 20 kg/ha/year in the acid-sensitive regions of Eastern Canada. In the United States, atmospheric models used in the 1990 NAPAP Integrated Assessment were described in a 1989 NAPAP publication with applications and performance evaluation status, ("Models Planned for Use in the NAPAP Integrated Assessment"). U.S. estimates of current, future, and relative (percentage change) wet sulphate deposition, assuming full implementation of U.S. and Canadian control programs, are shown in Figure 3.

Efforts have begun under the Agreement to identify and resolve differences in the details of the estimates of current and projected wet sulphate deposition from the respective assessments. Additional efforts also have begun to study and extend the wet deposition estimates to total sulphate

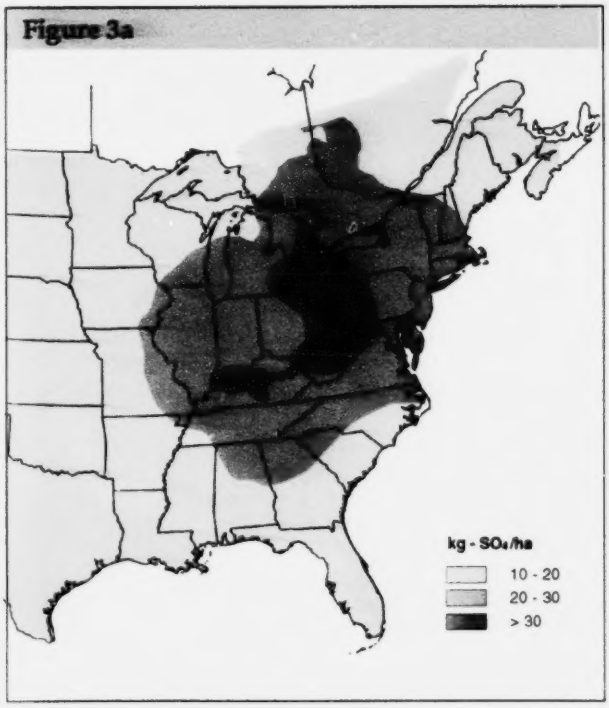
Figure 2a

Wet SO_4 deposition data 1982-1986 (kg/ha/yr). Current conditions—the observed 5-year (1982-1986) mean deposition values.

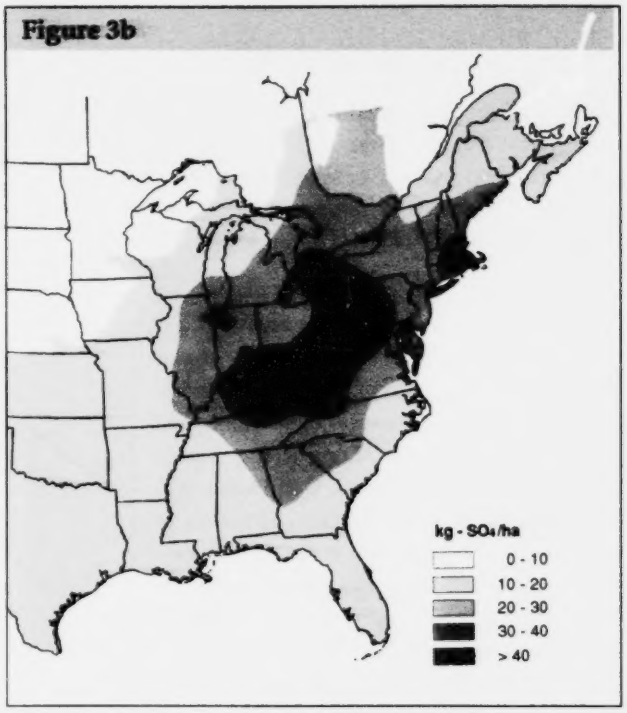
Figure 2b



Model predictions of deposition under conditions of full implementation of the SO_2 control program in Eastern Canada and a 10 million ton (9 million metric tonnes) reduction in 1980 emissions in the United States.



Wet sulphate deposition for 1982-85 (kg/ha) from monitoring sites (with smoothing-kriging).



RADM wet sulphate deposition for 1982-85 (kg/ha) from monitoring sites (with smoothing-kriging).

deposited. This coordinated review is expected to result in a consistent assessment of the effect of the combined Canadian and U.S. control programs on air quality and deposition. Efforts also have begun to develop a common approach to the best use of the different atmospheric modeling tools for assessment purposes.

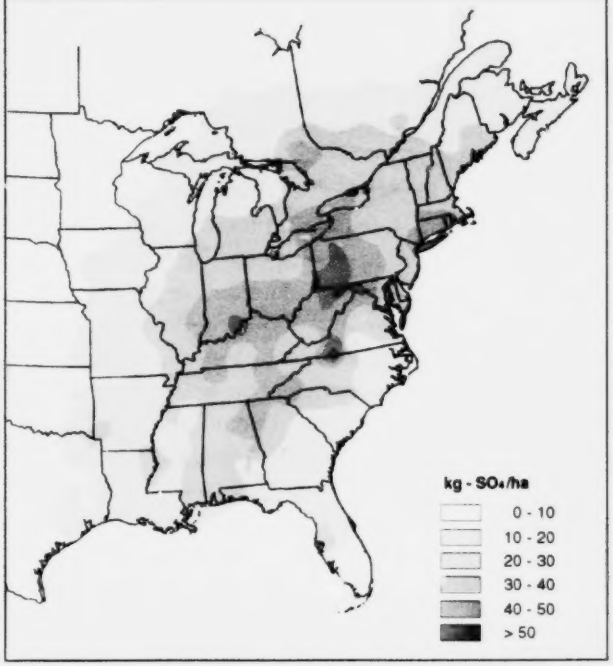
Planning is under way between EPA and Canadian federal and provincial agencies to exchange atmospheric model estimates of the transboundary effect of SO_2 emission controls in both countries on sulphate deposition reductions in Canada and the United States, respectively.

In the near future, information will be exchanged on atmospheric model estimates of nitrogen deposition. This work will augment continuing efforts related to wet sulphate, dry sulphur dioxide deposition, and sulphate air concentrations.

Atmospheric Model Evaluation

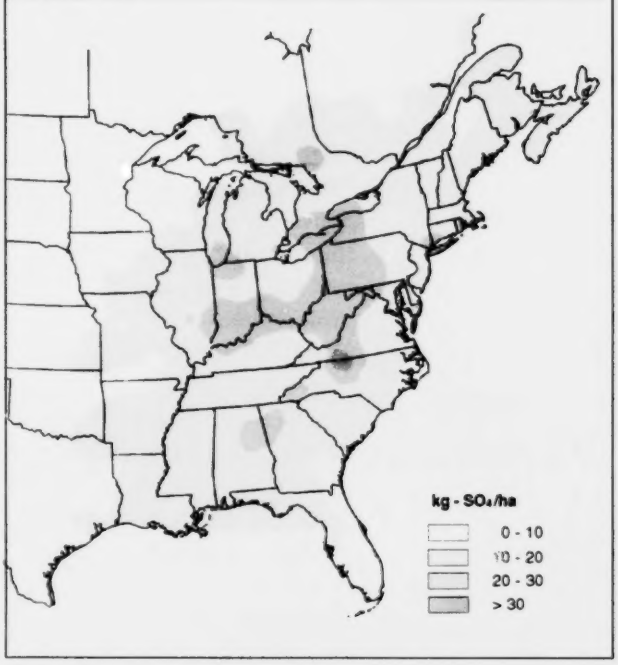
The two countries have been cooperating in a multi-year, bi-national Eulerian Model Evaluation Field Study (EMEFS) since 1985. The Preliminary EMEFS Evaluation of the advanced acidic deposition models developed in the two countries, the Regional Acid Deposition Model (RADM) in the United States and the Acid Deposition and Oxidant Model (ADOM) in Canada, has been completed. Results for RADM were presented in the NAPAP State of Science and Technology Report No. 5. Improvements to both ADOM and RADM stemming from the findings of the preliminary evaluation have been completed in 1991. The large under-prediction

Figure 3c



RADM wet sulphate deposition for 1982-85 (kg/ha).

Figure 3d



RADM wet sulphate deposition for 2010 (kg/ha).

of sulphate deposition in the earlier versions' predictions has been virtually eliminated for both models.

Phase 1 of the EMEFS program will be completed in 1992. Two joint workshops were held in 1991 to exchange and discuss model evaluation results. Diagnostic probing of the ADOM and RADM models will continue to be jointly coordinated through the EMEFS process. This diagnostic analysis is based on comparisons against special Canadian and U.S. aircraft and surface measurements collected under EMEFS.

Plans for the cooperative work of Phase 2 of the bi-national EMEFS evaluation have been developed and priorities for specific test periods established. Phase 2 is expected to continue through 1993. The emphasis of the RADM and ADOM evaluation is expected to shift from sulphur to nitrogen and ozone. Although several of the key issues regarding sulphur have been successfully dealt with in the improvements stemming from the Preliminary and Phase 1 evaluation work, sulphur predictions will continue to be examined because of the importance of sulphur in the Air Quality Agreement.

Cooperative work on the evaluation of the atmospheric models will be expanded under the Agreement to include the evaluation of models used to estimate seasonal and annual averages of sulphur deposition and ambient sulphate concentrations for assessment purposes.

Atmospheric Model Development

Longer range plans for model development also are being coordinated with bi-national participation. A North American Consortium on Advanced Modeling of Regional Air Quality (CAMRAQ) is a major vehicle for this coordination and information exchange. CAMRAQ includes several industrial research organizations as well as federal, provincial, and state agencies. The model development efforts will set a high priority on the extension of acid deposition models to incorporate regional particulates. Explicit inclusion of particulates will produce atmospheric models that give a more accurate assessment of visibility protection and air quality deterioration. This development effort will directly support visibility protection efforts called for in the Agreement.

DEPOSITION AND AIR CONCENTRATION MONITORING NETWORKS AND RESULTS

In Annex 2 of the Air Quality Agreement, Canada and the United States have agreed to coordinate their air pollutant monitoring activities for the purpose of determining and reporting on air pollutant concentrations and deposition. Since the deposition of sulphur and nitrogen compounds is linked to both acidic deposition and acidifying emissions, it is the focus of the discussion in this section. The simple measure of acidity, pH, offers a limited appreciation of the deposition phenomenon and is therefore not used in this discussion.

Acid deposition is traditionally considered in terms of wet and dry components. Wet deposition is the product of the con-

Wet deposition monitoring site.

centration of a species in precipitation and the amount of precipitation. Trends in wet deposition therefore reflect the trends in both concentration and precipitation amount. Sulphate and nitrate wet deposition has been monitored intensively in Canada and the United States throughout the 1980s by federal, state, provincial, and industrial monitoring networks, and results are reported here.

Dry deposition is not amenable to such monitoring methods. Moreover, studies are hindered because cost-effective direct measurement systems are not available. Dry deposition is estimated in the United States by the inferential approach for the 50-station National Dry Deposition Network (NDDN) and for the 9-station National Oceanic and Atmospheric Administration (NOAA) research network. In Canada, dry deposition is determined at 11 sites using a similar approach. The inferential approach used to calculate dry deposition in Canada and in the United States determines deposition flux as a product of measured concentration and as a modeled deposition velocity based on measurements of meteorological variables and physical/biological surface conditions, and provides relevant information at a reasonable cost. Other approaches to measuring dry deposition, such as eddy correlation, throughfall, and gradient processes, are in the exploratory phase of development. Although the latter "direct" flux measurements have not been used in routine monitoring programs, they are used at selected sites in the United States for comparison to inferential measurements.

Monitoring networks are important in the context of the Air Quality Agreement. Specifically, data on the concentration and deposition of acidic compounds and ozone will be collected to:

- assess the effectiveness of emission reduction requirements;
- support aquatic and terrestrial effects monitoring and research;
- determine regions of the continent at risk;
- assess materials damage;
- perform model maintenance and application;
- determine transboundary impacts; and
- support water quality determinations.

Environment Canada monitors wet and dry deposition within the Canadian Air and Precipitation Monitoring Network (CAPMoN). Most provincial Ministries of the Environment in Canada also carry out wet deposition monitoring. The combined federal and provincial wet deposition data are archived centrally in the National Chemistry Data Base (NATCHem).

As a result of the CAA, the United States created the Clean Air Status and Trends Network (CASTNET), which reflects a multi-agency, multi-program approach to large-scale monitoring and assessment. The participants in CASTNET include federal and state agencies and universities. The CASTNET program will provide a means to coordinate with Canada the monitoring of acid deposition and facilitate the exchange of information as agreed to in the Air Quality Agreement.

In the United States, the existing National Atmospheric Deposition Program/ National Trends Network (NADP/NTN)

Wet deposition data from the largest and most geographically diverse of these networks have been combined to produce maps showing the spatial patterns of wet deposition in eastern North America.

Figure 4

1980 wet SO_4 deposition—sea salt corrected (kg/ha/y).

1984 wet SO_4 deposition—sea salt corrected (kg/ha/y).

1988 wet SO_4 deposition—sea salt corrected (kg/ha/y).

will be relied upon to provide the basic framework for the wet deposition monitoring data. The CASTNET program will place additional wet and dry deposition monitoring sites in areas of the United States that are currently under represented. These areas include sensitive ecosystems, such as high elevation sites and coastal regions. The expanded NDDN (CASTNET), NOAA network, and the NADP/NTN will provide weekly total nitrogen and sulphur deposition, ozone, and sulphur dioxide concentration data. These data will be combined with data from the Canadian networks to estimate the spatial patterns of total deposition across North America.

In the United States, a number of stations offering detailed daily measures of wet and dry deposition parameters will be operated by NOAA under their new Atmospheric Integrated Research Monitoring Network (AIRMoN). This network is designed to provide a timely indication of the localized effects of emission controls on the atmosphere and on deposition from it, for a smaller number of sites selected to reveal the consequences of controls in some areas of special interest.

Wet deposition data from the largest and most geographically diverse of these networks have been combined to produce maps showing the spatial patterns of wet deposition in eastern North America. Figure 4 shows the annual wet deposition distributions of sulphate (corrected for sea salt within 100 km of the ocean) across eastern North America for the years 1980, 1984, and 1988. Figure 5 shows the correspond-

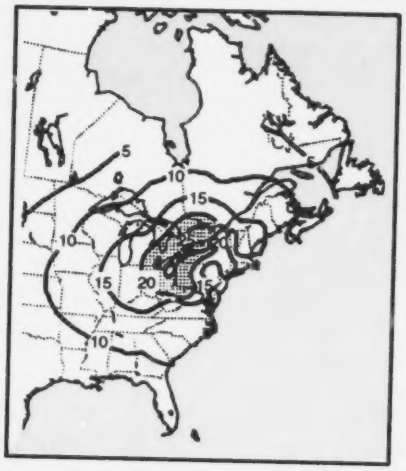
ing distributions of nitrate. The annual patterns (separated by 4-year intervals) provide a useful baseline for assessing possible spatial and temporal changes throughout the 1980s and future changes in the patterns. It is worth noting that the patterns represent regional-scale deposition and are based on measurements taken away from large emission sources.

Deposition monitoring, like atmospheric model development and the production of emission inventories, is an evolutionary process. Refinements in the collection and analysis of data have led to continuing improvements in the production of deposition maps, and future work will lead to even more improvements.

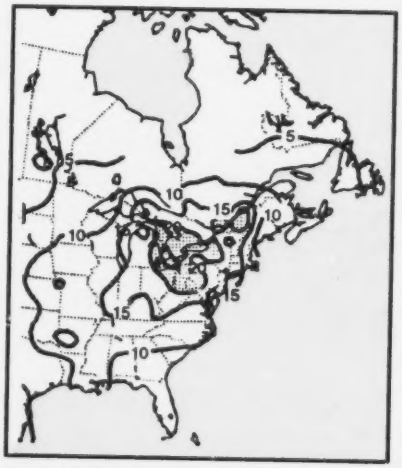
Air concentration and dry deposition of sulphate and nitrate have not been monitored in the United States and Canada to the extent that wet deposition has been. Figure 6 shows the existing air concentration and dry deposition monitoring sites and displays median SO_2 air concentration values recorded in 1989 at these sites in the United States and Canada. The map shows that relatively higher levels (generally above 10 $\mu g/m^3$) of SO_2 were found in a roughly rectangular area bounded by southern New York, northern Virginia, central Illinois, and northern Illinois. Concentrations generally decline as one moves away from this region. The concentration data are used to calculate dry deposition using the inferential approach.

The values in Figure 6 should be viewed as snapshots; they represent data only from 1989, and are the products of two different sampling time periods. The Canadian sites monitor on a daily basis,

Figure 5



1980 wet NO_3 deposition (kg/ha/y).



1984 wet NO_3 deposition (kg/ha/y).

1988 wet NO_3 deposition (kg/ha/y).

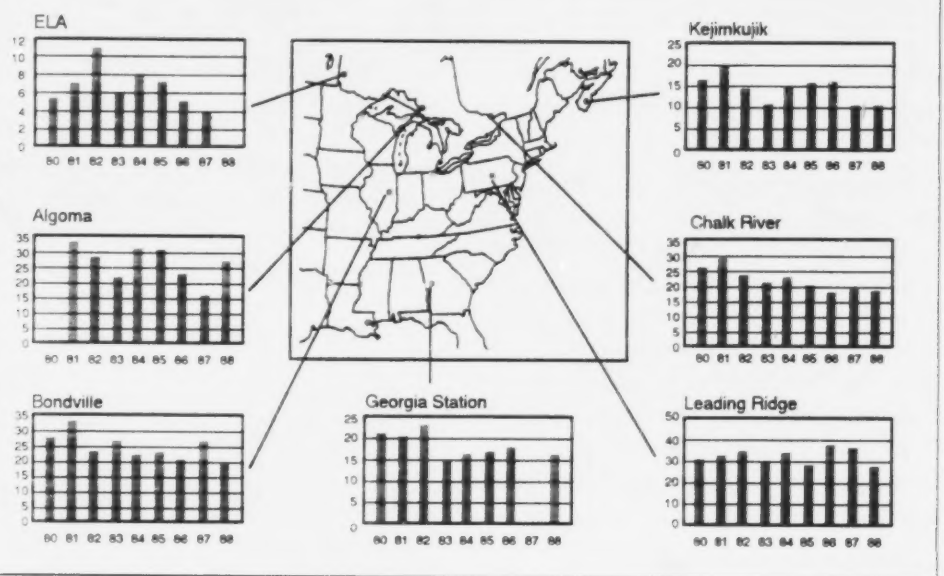
Figure 6

Median 1989 SO_2 air concentrations ($\mu g/m^3$) at CAPMoN and NDDN sites. At Penn State, the CAPMoN value appears above the NDDN values.

while the U.S. sites operate on a weekly schedule. These different sampling periods could lead to systematic differences in the data reported by the networks. However, at Pennsylvania State University, Canadian and U.S. sampling instruments operate within about 15 km of each other. The maps for 1989 indicate that, for the annual medians at least, the networks' data are comparable. Actual dry deposition fluxes have not been calculated from the air concentration data for the 1989 monitoring period. The patterns for dry deposition could be substantially different than those for the air concentrations.

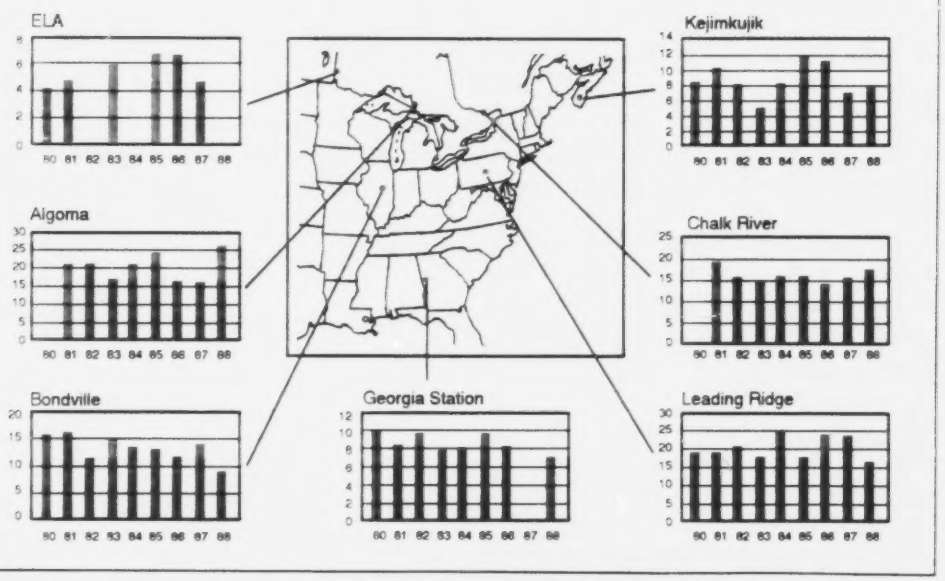
Figures 7 and 8 are simple bar charts of annual wet deposition of sulphate and nitrate, respectively, at seven sites across North America. It is apparent from these figures that annual wet deposition is highly variable on a year-to-year and site-to-site basis. This variability is related not only to annual variations in emissions, but also to variations in meteorology—especially wind and precipitation patterns. As a result, it is entirely possible for emissions to remain roughly constant over several years while the deposition varies considerably. This natural variability has major implications on the length of time required to detect long-term trends in deposition.

Figure 7



Annual wet deposition of sea salt corrected sulphate ($kg\ h^{-1}\ y^{-1}$) at four CAPMoN sites in Canada and three NADP/NTN sites in the United States.

Figure 8



Annual wet deposition of nitrate ($kg\ h^{-1}\ y^{-1}$) at four CAPMoN sites in Canada and three NADP/NTN sites in the United States.

A strong correlation supports the hypothesis that sulphate deposition has had a direct effect on the chemistry of surface waters in many parts of North America.

U.S. and Canadian scientists are currently working on a common trends analysis approach for both countries.

In Canada, trends in concentration data for sulphate and nitrate in precipitation have been analyzed at five CAPMoN sites. The trends were determined using CAPMoN data in a best-fit time series model that accounted for inherent seasonal cycles, long-term cycles, long-term trends, and the relationship between precipitation depth and concentration. The relationship between the modeled and calculated means is quite good.

Sulphate in precipitation at the Canadian sites generally decreased from the early to late 1980s (roughly 1986-1987), after which time it stayed approximately constant to 1990. In contrast, nitrate concentrations showed no significant trend upward or downward at three of the five sites, increased dramatically from 1981 through 1990 at the fourth site, and cycled through a decrease and an increase at the fifth site. It remains for researchers to establish the linkage between these trends and trends in emissions and meteorology.

The goal is to be able to describe total sulphur deposition. Research is currently ongoing so that wet and dry deposition fluxes in kg/ha can be combined to give total deposition.

In Annex 2 of the Air Quality Agreement, Canada and the United States agreed to cooperate and exchange information with respect to (a) their monitoring of the effects of changes in air pollutant concentrations and deposition with respect to changes in various effects categories, and (b) their determination of any effects of atmospheric pollution on human health and ecosystems. In the following sections, the effects of acidic deposition on aquatic systems, forests, human health, and materials are discussed. Programs to protect visibility were discussed in an earlier section of this report.

It was the observations of aquatic effects in the 1970s that initiated the widespread scientific and political interest in acidic deposition. Because research began relatively early, understanding the impact of acidic deposition on aquatic resources is in many ways more developed than for other ecosystem components.

Terrain Sensitivity and Regions of Concern

Canada

Approximately 4 million km^2 (43 percent of Canada's land area) is considered potentially sensitive to changes in chemistry and biology as a result of changes in acidic deposition chemistry. These sensitive areas correspond, to a major degree, to the Canadian Shield. The coincidence of sensitive terrain and elevated acidic deposition defines the area of primary concern. In Canada, it is restricted to the southeastern portion of the country (Figure 9).

United States

Those areas where lakes and streams would be expected to change in response to changes in sulphur and nitrogen deposition are New England, the Adirondacks, the Mid-Atlantic Highlands, the Mid-Atlantic Coastal Plain, the Southeastern Highlands,

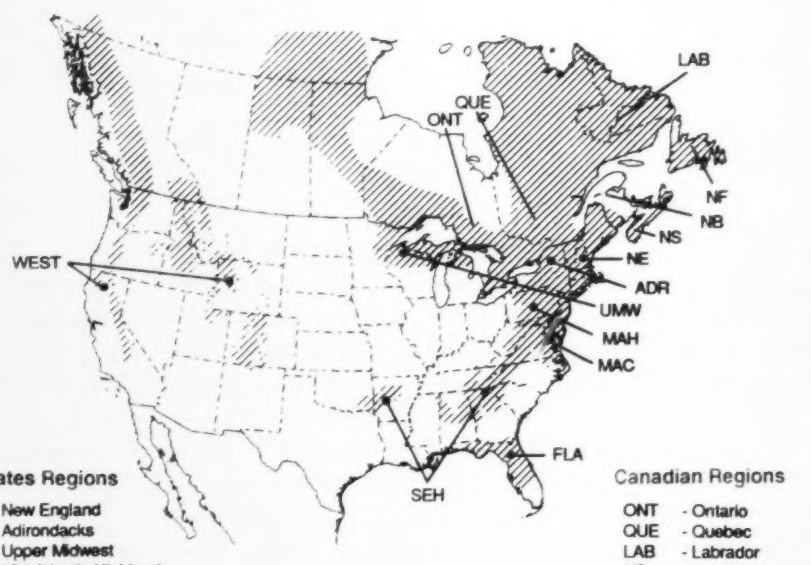
Florida, the upper Midwest, and portions of the West (Figure 9).

Sulphate Deposition versus Surface Water Concentrations

Sulphate concentrations in many dilute surface waters are controlled by the magnitude of sulphur deposition. A plot of median regional wet sulphate deposition versus median surface water sulphate concentration yields a positive relationship (Figure 10). Exceptions are easily explained such as regions receiving high dry deposition (e.g., Sudbury), or regions having sulphate-absorbing soils (e.g., Southeastern Highlands). The relatively small scatter of the remaining points in Figure 10 reflects regional differences in the relative magnitude of wet and dry deposition, climate geological sources of sulphate, terrain physiography, and other system variables.

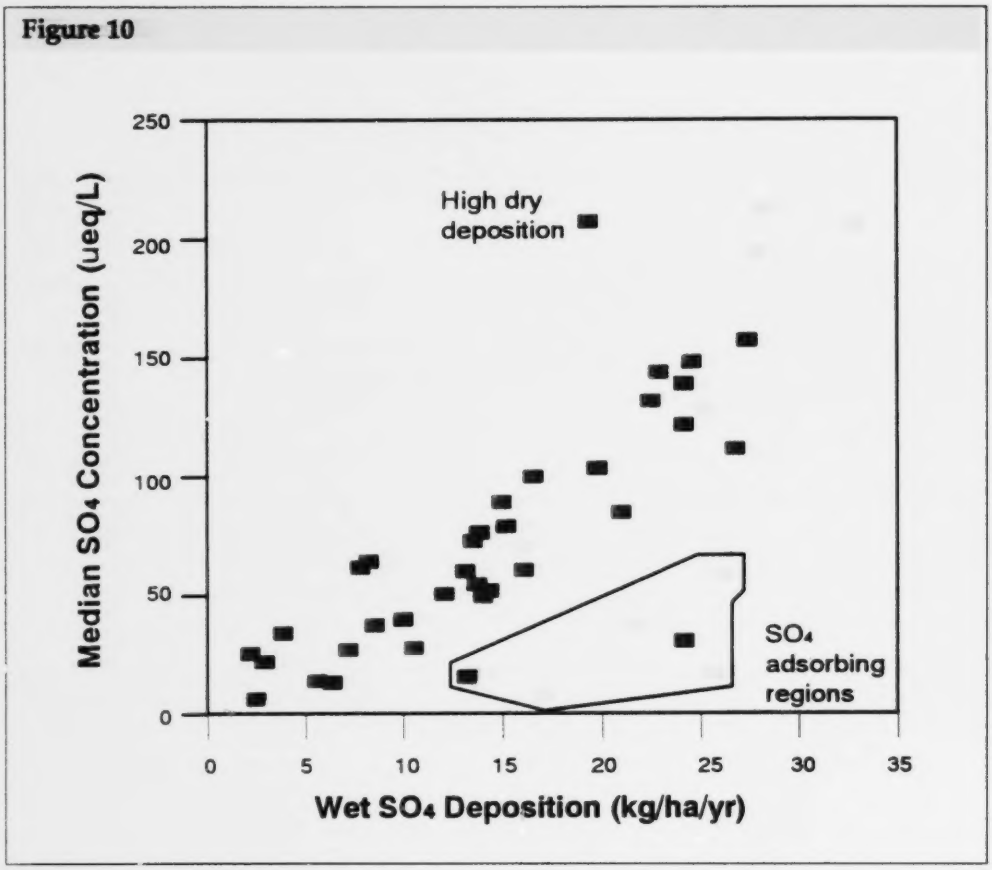
The strong correlation evident in Figure 10 supports the hypothesis that sulphate deposition has had a direct effect on the chemistry of surface waters in many parts of North America. Surface waters react to the increased sulphate in one or more of the following ways: decreasing acid neutralizing

Figure 9



Location of Canadian and United States regions of concern. Markers indicate general location of region rather than specific points. More regions are indicated than discussed specifically in the text. Data for all regions listed are available for assessment of change.

Figure 10



Relationship between median sulphate concentrations in lakes and wet sulphate deposition.

capacity (ANC) and pH, increasing base cations, and/or decreasing organic anions. Surface waters with an ANC ≤ 0 µeq/L are defined as acidic, while those with ANC ≤ 50 µeq/L are defined as extremely sensitive to acidification. In addition to the influence of sulphate deposition, the ANC of surface waters can increase with increasing base cations and/or decreasing organic anions.

Current Chemical Conditions in Regions of Concern

Canada

Lakes in the Atlantic provinces of Canada and Quebec generally have lower base cation and ANC concentrations than those in Ontario primarily due to differing terrain geology. Thus, lakes in the Atlantic and Quebec regions are typically more sensitive to acidic deposition than lakes in either Ontario or the eastern United States. The Sudbury region in Ontario also has acidic lakes localized around a large emitter of sulphur dioxide. There are in the order of > 14,000 acidic lakes >1 ha in size and > 31,000 acidic lakes > 0.18 ha in size in southeastern Canada. Regional acidification of eastern Canadian lakes is primarily due to sulphate deposition, not organic acids.

United States

Within the regions shown on Figure 9, 8 percent of the streams and 4 percent of the

lakes were acidic and about 20 percent of both lakes and streams had ANC below 50 μeq/L. Florida had the highest proportion of acidic surface waters among the National Surface Water Survey (NSWS) regions (39 percent of the streams and 23 percent of the lakes), followed by the Adirondacks (14 percent of lakes) and the Mid-Atlantic Coastal Plain (12 percent of streams). The remaining regions have < 10 percent acidic surface waters and the western United States and the Southeastern Highlands have < 1 percent. Organic acids and sulphate from acid mine drainage significantly contribute to the acidification of waters in some areas, particularly Florida (organics) and the mid-Appalachians (acid mine drainage). However, atmospherically deposited sulphate is the dominant anion in 75 percent of the acidic lakes and almost 50 percent of the acidic streams. Overall, there were 1,180 acidic (ANC ≤ 0) lakes larger than 4 ha and 4,520 acidic streams in the assessed regions, representing an acidic lake area of 263 km^2 and 7,900 km of acidic stream length.

The above assessments reflect average conditions. Acidic deposition contributes to episodic depressions of ANC that occur during high flow periods associated with rainstorms and snowmelt. When these episodes are taken into account, the number of acidic lakes and streams in many areas will increase up to threefold (including areas of the western United States).

Differences in the chemical variability of U.S. and Canadian surface waters are largely due to much greater geological diversity in the United States.

Current Conditions: Biological Response

Acidification of aquatic ecosystems causes adverse effects on many aquatic organisms. A direct effect is the toxicity of hydrogen ion, which can be accentuated if calcium concentrations are low. Toxic concentrations of aluminum occur in many chronically or episodically acidified surface waters as well. Indirect effects of acidification are usually changes in organisms caused by interactions

with other directly impacted organisms, e.g., starvation through disappearance of other food organisms.

Damage to fish populations often begins to occur when pH < 6.0. Minnow species and other smaller fishes are frequently more sensitive than many sport fishes. Successful reproduction can occur in formerly non-reproducing populations by reversing acidification.

Applications of fish response models suggest that U.S. waters having acid-base chemistry unsuitable for the survival of acid-sensitive fish species range from < 5 percent in areas such as the Upper Midwest to near 60 percent for upper stream reaches in the Mid-Atlantic Coastal Plain. Brook trout is one of the species most widely distributed in waters sensitive to acidic deposition and is also an important sport fish in these regions. An estimated 13 to 14 percent of the NSWS lakes in the Adirondacks classified as potential brook trout habitat currently have acid-base chemistry unsuitable for brook trout survival.

Case Studies: Canada and the United States

Ontario

The chemical condition of surface waters can improve under decreased sulphur deposition. An illustrative case is the surface waters near Sudbury, Ontario. Sulphur dioxide emissions from the smelters at Sudbury, in central Ontario, declined from about 2.2×10^6 tonnes in 1950 to 1972 to about 0.6×10^6 tonnes by 1979 to 1985. Due to the replacement of short stacks by a single tall stack (1972), local deposition has decreased by as much as 75 percent. Several lakes near Sudbury have shown substantial decreases in lake water sulphate; increases in pH; and decreases in Al, Cu, Ni, and Zn. Since 1986, the sulphate and pH trends in Sudbury area lakes have stabilized. These changes in sulphate and pH also were found in lakes outside the immediate influence of the smelters. The decrease in SO_2 emissions at Sudbury has resulted in a rapid reversal of chemical acidification. However, evidence for the reversal of biological effects is less extensive, e.g., trout populations in a few lakes relatively remote from the smelters have responded positively to an increase in pH.

The Algoma area of central Ontario lies west of and outside the direct influence of the Sudbury smelters. Lakes in Algoma respond rapidly to changes in reduced sulphate deposition with either increased pH and ANC or decreased base cations. Two lakes without fish in 1979 developed white sucker populations by 1986 through invasion from downstream populations when lake pH approached 5.5.

Plastic Lake is a sensitive lake in south-central Ontario. ANC decreased in Plastic Lake between 1979 and 1985 by about 2 $\mu eq.L^{-1}yr^{-1}$. There was a contemporaneous pH and base cation decline, but no significant change in sulphate. Dissolved organic carbon also decreased and water transparency increased as the lake became more acidic. Major biological changes also occurred in Plastic Lake, although the pH decreased only from 5.8 to 5.6. It is likely that 75 to 80 percent of the original ANC of Plastic Lake may have been lost before studies began in 1979. Since 1985, the pH and ANC of Plastic Lake have remained constant despite a sharp decrease in sulphate and H^+ deposition in southern Ontario in the past decade. This is ex-

plained by continuing release of sulphate and acidity previously stored in wetland areas in the catchment.

Nova Scotia

One-third of the available Atlantic salmon habitat in Nova Scotia has been lost due to acidification since 1950. In Nova Scotian rivers with pH > 5.0, juvenile Atlantic salmon are present at population densities which are normal for the region (20 to 30 fish/100 m). No juveniles are found in rivers with pH < 5.0 except those that have some tributaries with higher pH. Liming of headwater lakes may be used in some cases to achieve a short-term restoration of acidified salmon habitat in Nova Scotia. The limed lakes release ANC to the downstream habitat. The major disadvantage is that most Nova Scotian lakes have a turnover time of less than one year, hence annual reapplication of lime is required.

Adirondack Mountains

The chemistry of 16 lakes has been monitored since 1982. Most lakes exhibit decreasing sulphate concentrations consistent with decreases in sulphur deposition in the 1980s; however, increasing lake water nitrate levels could not be attributed to change in deposition. None of the Adirondack lakes exhibit the increase in ANC expected from a decrease in sulphate; in fact, ANC declined in four lakes. Increases in nitrate and uncertainty in the trends for base cations and aluminum confound the simple expectation that ANC will increase as sulphate concentrations decrease in Adirondack lakes.

Catskill Mountains

The Catskill Mountains are in a high deposition region of southern New York where streams are the primary aquatic resource; eight streams have been monitored there since 1983. Other source water streams for the New York City water supply have data records extending back to 1915. Catskill streams show large short-term variability, long-term decreases in sulphate and increases in nitrate, and little overall trend in ANC or pH. Sulphate concentrations have been decreasing since circa 1970, consistent with the timing of maximal sulphur deposition in the northeastern United States, while nitrate concentrations have been increasing since circa 1970.

FORESTS

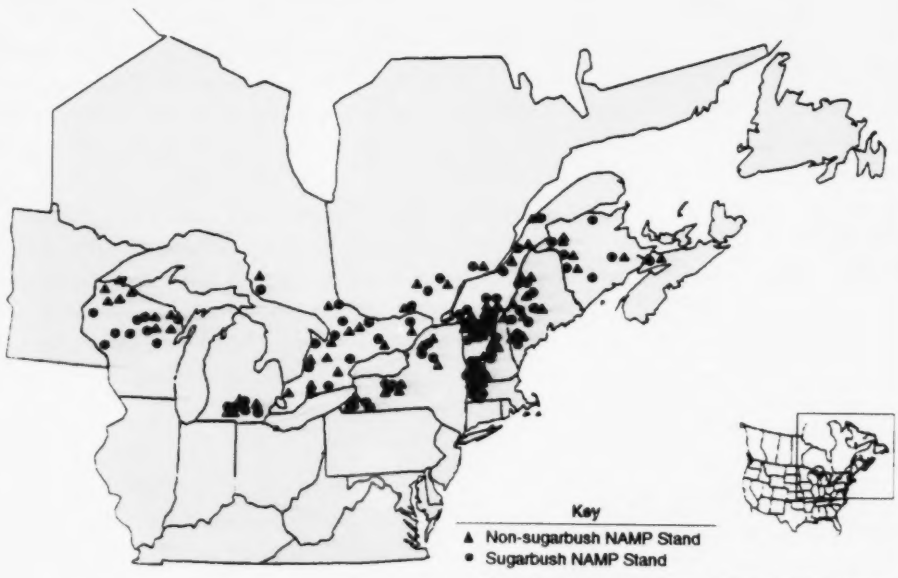
Large areas of forests in the United States and Canada are routinely exposed to acidic deposition, sulphur dioxide, oxides of nitrogen, and other pollutants. There is general agreement that the majority of forests in North America are not extensively affected by acidic deposition. In the east, only certain tree species in areas receiving the highest load of pollutants via fog or clouds are experiencing damage.

The North American Maple Project

The North American Maple Project (NAMP) was implemented under a Memorandum of Understanding between Forestry Canada and the U.S. Department of Agriculture (USDA), with significant collaboration of agencies at the provincial and state level.

The purpose of NAMP was to determine the rate of change in sugar maple condition over time. A network of 166 five-plot clusters was established in 84 active sugarbushes (tapped stands) and in 82 unmanaged, natural stands in Canada and in

Figure 11



Distribution of plot clusters for the North American Maple Project (1988/1989).

the United States from Wisconsin in the west to Nova Scotia in the east (Figure 11). In 1990, 93 percent of sugar maples were found to be in a healthy condition. Only 7 percent of sugar maples evaluated had 20 percent or more crown dieback. There was no significant difference between crown condition in sugarbushes versus unmanaged forest stands. There was no relationship between crown condition and wet sulphate deposition. Natural causes such as drought and abnormal winters appear to be the most likely causes of sugar maple decline although the role of acidic deposition and ozone as predisposing factors cannot be ruled out at this time.

Current State of Forests

Canada

The health of Canada's forests has been monitored nationally since 1984 by the Acid Rain National Early Warning System (ARNEWS). A common set of measurements is used at 103 permanent sample plots located in all 10 provinces to detect early signs of air pollution damage in Canada's forests.

Data on tree mortality and crown condition for 16 conifers and 9 hardwoods indicate that there is no evidence of a national decline in Canadian forest health. With the exception of white birch in southern New

Brunswick, tree mortality was within "normal" ranges (1 to 3 percent) and was attributed to natural stresses. Balsam fir mortality in Eastern Canada exceeded 3 percent due to the spruce budworm.

No sugar maple mortality was recorded by ARNEWS in the Maritimes. Sugar maple mortality was 1 percent annually in Quebec and 3 percent annually in Ontario. In some localized areas, mortality reached 25 percent in certain years. The general crown condition of sugar maples declined in Ontario between 1986 and 1990. This was attributed to severe drought conditions.

Mortality of white birch in southwestern New Brunswick was 11 percent between 1982 and 1990. Air pollutants are implicated as contributing factors predisposing white birch to decline.

United States

In 1990 the U.S. Forest Service, with EPA and state forestry agencies, initiated a National Forest Health Monitoring Program. Currently, the program is operational in 10 eastern and 2 western states, with data collected from over 1,000 permanently established plots. Initial results for the six New England states in 1990 showed the forests to be in generally healthy condition, with no unknown health problems. The National Forest Health Monitoring Program is designed to be fully compatible with the Canadian ARNEWS.

There is no evidence of an overall or pervasive decline in forests in the United States, due to acidic deposition or any other stress factor. Moreover, there is no case of forest decline in which acidic deposition is known to be a predominant cause. Only in cases where forests are frequently

exposed to highly acidic fog or cloud water is there evidence that acidic deposition is a significant contributing factor to observed forest health problems. Research continues to assess the interactive effects involving air pollution and drought, pest infestation, and other stress factors.

The USDA Forest Service has reported widespread reductions in average tree growth rates within diameter classes in natural pine stands in the Southeast. Similar growth rate reductions have not been observed in plantations. Occurrence of the reported tree growth reductions in natural pine stands is an expected consequence of historical land use patterns, increases in stand age and competition, and other natural factors. However, data analyses constructed to date have not determined whether the tree growth reductions are greater or less than would be expected in the absence of acidic deposition and associated pollutants.

Efforts to evaluate pine growth trends at the stand level have identified unexplained variation but have been severely

limited by the nature of the available data. Whether acidic deposition or other air quality factors are significantly affecting the health and productivity of southern pines remains to be determined. A survey of visible symptoms of stress indicated that the crowns of most southern pine trees are healthy. However, ambient levels of ozone have altered seedling growth and physiology of some pine families in controlled experiments.

Effects of acidity on above-ground pine tissue in controlled experiments are generally non-significant. Available evidence does not support the hypothesis that acidic deposition has caused aluminum toxicity or nutrient deficiencies in southern pines.

Ozone stress is the predominant factor in a decline of ponderosa and Jeffrey pines in the San Bernardino Mountains near Los Angeles and in part of the Sierra Nevada Mountains. Ozone also may be contributing to red spruce decline at high elevations and is causing visible injury to foliage on sensitive genotypes of eastern white pine, black cherry, and many other species.

The extent to which ozone is affecting forest productivity and ecosystem diversity remains to be determined. Experiments with seedlings have shown that many species across the United States have genotypes that are adversely affected by ambient levels of ozone. It is difficult to extrapolate confidently the experimental results, because mature trees in forest stands may respond to ozone differently than seedlings grown under experimental conditions. In areas outside the Los Angeles Basin, effects of ambient ozone on tree species have not been shown to cause forest health problems other than visible injury and growth loss in sensitive individual trees.

Ecosystems/Watersheds/Soils

The flux of SO_4/NO_3 from the atmosphere through the forest ecosystem to aquatic ecosystems has been monitored and studied intensively at a number of calibrated watersheds. In northeastern North America, six such watersheds have been operating for different periods of time. Data have helped demonstrate that controlling emissions to reduce SO_4 deposition may reduce SO_4 leaching from podzolic soils. This suggests that the deposition of strong mineral acids is contributing to the leaching of base cations from some Canadian soils. Over the long term, this may reduce the fertility of some soils.

Long-term changes in the chemistry of some sensitive soils is expected from acidic deposition. It is uncertain whether this will result in reduced forest health, how much of the forest resource will be impacted, or how long it will take to occur. Modeling studies suggest that acidic deposition could have measurable effects on the chemistry of some southern U.S. soils within 50 years. Whether such changes will actually occur or affect forest growth remains to be determined. Beneficial effects on soil fertility due to nitrogen deposition may offset adverse effects due to accelerated leaching of base cations in the short term, followed by long-term decreases in nutrient status of the soils.

Individual Forestry Case Studies

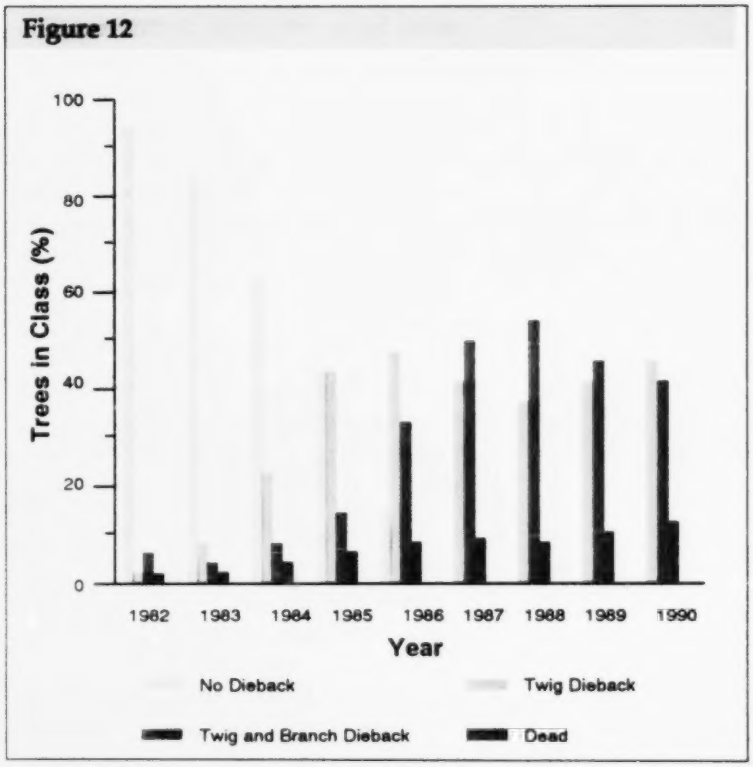
Coastal Fog and Tree Decline at Low Elevations

Two tree species growing along coastal regions of eastern North America have been in decline since the early 1980s. Historical evidence indicates that there have been increases in fog acidity (five- to ten-fold) and NO_3 concentrations since 1939, but no change in SO_4. Compared with mountain cloud chemistry in the Northeast, these coastal fogs are up to three times higher in the ionic concentrations and lower in pH.

Foliar decline symptoms have been observed on red spruce trees growing at a mid-coast site in Maine where acidic deposition in fog is greatest. Foliar browning and leaf fall early in the season have been observed on white birches in coastal southwestern New Brunswick since 1979. Insects and pathogens have been discounted as causal agents. The area has recently experienced high fog frequencies during the summer. Studies have demonstrated a relationship between hydrogen and NO_3 concentrations in fog and incidence of foliar browning.

The condition of white birch deteriorated markedly between 1982 and 1987 and then stabilized until 1990. In 1987, all trees examined were exhibiting some degree of decline. Twig and branch dieback reached 50 percent by 1987. Mortality increased to 11 percent in 1990 (Figure 12).

Figure 12



Birch decline.

Red Spruce Decline at High Elevations

There is experimental evidence that acidic deposition and associated pollutants can alter the resistance of red spruce to winter injury; through this mechanism, acidic deposition may have contributed to red spruce decline at high elevations in the northern Appalachians. Evidence of red spruce decline and pollutant involvement in the southern Appalachians is less substantial.

Red spruce that grows in the cloud-exposed forests of the northeastern U.S. mountains has been declining for 30 years. Repeated, severe winter injury was the primary inciting factor. With wind stress, insect pests, and fungal pathogens, it has served to sustain the decline.

Exposure-response experiments have provided support for the hypothesis that air pollution (particularly acids in cloud

water) has a role in the decline. Some results with seedlings and branches of mature trees indicate that airborne chemicals at current levels can reduce the cold tolerance of this species, which was already marginal in its ability to survive low temperatures and other stresses. Other results with seedlings show that ambient or near-ambient levels of acidic mist and ozone can, under some conditions, cause direct injury to needles and unfavorable alterations in biochemical and physiological processes. At present, it is not clear which, if any, of these effects are occurring in the field.

The current condition of red spruce in the southern Appalachians is not agreed upon by all investigators. Localized mortality has been reported, while more extensive surveys suggest that recent mortality has been low relative to mortality in the North. At present, areas of agreement are: (1) there was a deterioration of crown condition in the late 1980s, and (2) there is a recent decrease in growth at the highest elevations. Ongoing research has focused on the ability of acidic deposition to exacerbate nutritional stress through above- and, especially, below-ground effects. At present, there is little available evidence suggesting that the condition of red spruce in the southern Appalachians has deteriorated because of acid deposition and/or associated pollutants.

Agriculture

Agricultural crops are exposed regularly to acid deposition, sulphur dioxide, and ozone over large areas of North America. Acid deposition and sulphur dioxide have been shown in laboratory or field exposure studies to have the potential at higher than ambient doses to affect marketability, growth, and yield of a number of important species.

There is general agreement that acidic precipitation at current levels has not been responsible for crop yield reductions on a regional basis in Canada or in the United States. There is, however, the potential for foliar injury in southern California. Current levels of NO_x and SO_2 also do not appear to be affecting agricultural productivity on a regional basis.

The greatest concern is the impact of ozone on agricultural production in the United States and in Canada. Research results indicate that, depending on species, location, and exposure, yield reductions in crops have ranged from 0 to 56 percent at ambient ozone concentrations.

MATERIALS AND CULTURAL RESOURCES

The effect of acidic deposition on various materials has been a concern in both countries. It is difficult to make generalized statements about acidic deposition and materials damage because materials are subject to a variety of stresses.

NAPAP concluded that pollution is causing degradation of materials beyond that associated with natural weathering. Documented sensitive materials include carbonate stone and galvanized steel. Carbonate stone has been used in many cultural materials, like statues, monuments, significant public buildings, and gravestones, while galvanized steel is used in a multitude of end-uses. Research under NAPAP and other programs confirmed that rates of metals corrosion and carbonate stone dissolution are accelerated by dry

and wet deposition of acids. For carbonate stone and certain metals, such as galvanized steel, reactions with sulphur dioxide, wet deposited acids, and natural acidity from dissolved carbon dioxide all contribute to stone erosion and metal corrosion. Results from laboratory and field experiments indicate that pH 4 may be a critical level of acid exposure for marbles, limestones, and bronzes. In addition to wet deposition induced corrosion/erosion, dry deposition reacts with stone surfaces to form black crusts which disfigure the surfaces and cause disintegration and spalling of the stone. Similarly, the green patina on bronzes in urban environments is largely composed of copper sulphate compounds.

Research has provided the quantitative data that help define the contributions of wet and dry acidic deposition (including rainfall acidity caused by atmospheric carbon dioxide) to the corrosion of galvanized steel and the erosion of carbonate stone test samples under the ambient environmental conditions at field exposure sites. The separate effects of these environmental variables have been expressed in the form of dose-response functions for the corrosion of galvanized steel and the chemical erosion of carbonate stone. Weathering effects on complex shapes (sculpture, cornices, bridges) are far more severe than for flat surfaces (walls, roofs, test specimens). Laboratory experiments and measurements at buildings and monuments indicate that available dose-response functions represent minimum corrosion rates and minimum contributions from deposition to weathering/corrosion. However, to date, these dose-response functions have not been validated to the extent that they can be used to predict accurately the incremental change to structural components of those materials resulting from a change in one of the important environmental variables.

The fact that the corrosion depends on more than just the effects of sulphur dioxide indicates that a specified decrease in the sulphur dioxide level will not lead to the same decrease in the corrosion/weathering.

Other materials that have been studied and discussed in the NAPAP documents include wood and painted surfaces. One concern important to consumers is the impact of acidic deposition on automotive finishes. Damage in the form of spotting has been observed in some laboratory simulations, but comprehensive studies of the effects of weathering and acidic pollutants on automotive paints have not been published. NAPAP-supported research corroborated the fact that aluminum-flake maintenance paints may be susceptible to degradation caused by acidic deposition. The uptake of SO_2 for these paints is increased relative to that of inert substrates and some other paint formulations. Some leaching of the aluminum in these paints was detected in runoff studies. Based on these results, automotive formulations containing aluminum flake would also be expected to have similar reactivity to acidic deposition.

In some cases, preservation methods are available to prevent environmental damage to cultural materials, notably the use of protective coatings for metals, such as lacquers or wax. However, once severe corrosion has occurred, it is difficult to restore the original luster of bronze sculptures. Theoretically, all outdoor

bronzes could be protected from corrosion by expenditures of $10 to $100 million per year in the United States. In contrast to metal corrosion control, there are no generally accepted methods to prevent stone decay accelerated by either wet or dry deposition. For many non-cultural materials, economic costs from materials degradation involves factors such as service-life cycle, maintenance practices, and behavioral variables.

In the United States, the areas having the largest numbers of cultural materials coincide with the regions of highest acidic deposition. Most of the nation's historic battlefields, especially those with many commemorative monuments, are located east of the Mississippi River. It is estimated that some 15 to 50 percent of historic stone buildings are sensitive to attack by atmospheric acids; 20,000 to 50,000 outdoor monuments are exposed nationwide; and about one-third of the approximately 100 million grave markers are made from acid-sensitive materials.

HUMAN HEALTH

Due to the complexity of atmospheric transformation processes involved in the development of acidic aerosols, a wide array of pollutants are involved, including sulphur oxides, nitrogen oxides, volatile organic compounds, ozone (O_3), and organic acids. Only the effects of acidic aerosols will be discussed here. Major reviews of these other pollutants are readily available.

Health Effects

Acidic aerosols are acidic particles suspended in a gas having a net acidity. As such, they are complex mixtures having substantial geographic and temporal variability. Understanding the health risk of acidic aerosols requires integration of knowledge of exposure, susceptible sub-populations, and exposure-response relationships. The current primary concerns for health risks center on acidic sulphates and the potential for acute effects on the pulmonary function of asthmatics, effects on clearance of particles from the respiratory tract, an increased incidence of acute bronchitis in children, and suggestions of premature mortality in sensitive populations. The sparsity of information on other acidic species precludes their discussion, but indicates that further research may be warranted.

Animal toxicology and human clinical studies have shown that the potency ranking of sulphate aerosols is H_2SO_4 > NH_4SO_4 > $(NH_4)_2SO_4$. Therefore, most of these controlled studies have used H_2SO_4. These data suggest that hydrogen ion (H^+) is the species of concern and that the specific compound also has an influence. This also implies that measurement of ambient H^+ alone will not be fully predictive of effects on a population. Animal studies, correlated to some human studies, have led to a hypothesis that chronic exposure to H_2SO_4 may contribute to the development of chronic bronchitis. Supporting evidence in animals includes findings of slowed mucociliary clearance and struc-

tural alterations of the lung, some of which persist after chronic exposure ceases. Research with laboratory animals also has demonstrated that H_2SO_4 can synergistically interact with O_3 and other particles. Thus, other co-occurring pollutants can enhance the effects of acidic aerosols.

Controlled human exposure studies of the acute effects of H_2SO_4 on pulmonary function have provided varying concentration-response relationships, with differences between studies perhaps reflecting differences in aerosols, exposure regimes, exercise levels, and human subjects studied. Generally, healthy volunteers are not affected at H_2SO_4 concentrations high above ambient levels. Several (but not all) studies indicate that asthmatics can be susceptible to exposures from 100 to 1,000 $\mu g/m^3$ H_2SO_4. Preliminary results using 68 $\mu g/m^3$ H_2SO_4 suggest that adolescent asthmatics are more sensitive. There is further evidence that concomitant exposure to other pollutants such as SO_2 (0.5 ppm) or O_3 (0.12 ppm) may enhance the irritative bronchial response to acidic aerosols. Acute exposure to H_2SO_4 also slows clearance of test particles from the airways of healthy and asthmatic humans. For example, a 1-hour exposure to 100 $\mu g/m^3$ H_2SO_4 substantially depressed clearance. This effect is of concern since it implies that inhaled particles and natural debris that are normally cleared by the respiratory tract may build up. Although the evidence from clinical studies is highly suggestive of adverse effects of acute H_2SO_4 exposures, it is important to recognize that much remains to be confirmed.

A recent study in Canada observed small decreases in children's lung function that occurred during times of high air pollution. Acid levels reached a maximum of about 50 $\mu g/m^3$ (1 hour average), and ozone levels were as high as 143 ppb.

One Canadian study compared the respiratory health of 7- to 12-year-old children from two communities, one experiencing high, and one experiencing low levels of long-range transported air pollution. Children in the community with higher levels of pollution had statistically significant lower levels of forced vital capacity and forced expiratory volume. While it was not possible to attribute the effect to a specific pollutant, it is noted that the two communities differed far more in their sulphate exposures than they did in other measures of pollutants. In a second Canadian study, the health comparison was conducted in a total of 10 communities, and it also demonstrated a small but statistically significant decrement in the same lung functions. Children in the more polluted area also had a higher incidence of upper respiratory infections. It is believed that the observed difference is likely due to the coexistence of acidic aerosols and other pollutants, i.e., O_3, PM_{10}, SO_2.

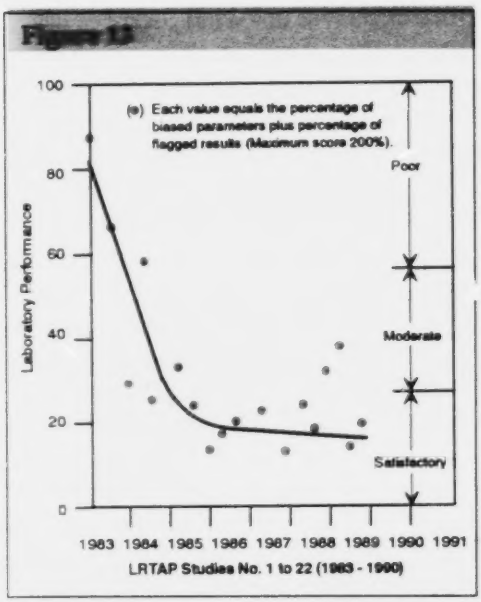
The Six-Cities Study in the United States has examined the relationship between air pollution and health for the past decade. Although direct measurements of airborne acidity were not performed during the main study, subsequent measurements revealed periods of high aerosol acidity in several cities and at varying times. Using these data and reanalyses of the original symptoms prevalence data, it was observed that acid concentrations were directly associated with an increased prevalence in reported bronchitis in children.

Along the eastern Canadian-U.S. transboundary areas, aerosol acidity is dominated by acidic sulphates (i.e., sulphuric acid [H_2SO_4] and ammonium bisulphate [NH_4HSO_4]). The level of acidic aerosols during weather episodes also may have a distinct diurnal pattern, with peak acid levels occurring in daylight hours, especially in the summer season. Current measurement and population exposure data for acidic aerosols are sparse. The highest reported short-term (1- to 12-hour) values ranged up to 30 to 50 $\mu g/m^3$ H_2SO_4 (or equivalent H_2SO_4). Such peaks are infrequent, but 24-hour values of 5 to 15 $\mu g/m^3$ may occur with regularity. The highest peaks occur downwind of major SO_2 emissions, from either large single sources or urban source areas. However, these data are insufficient to estimate with much precision human exposure patterns for acidic aerosols across the transboundary area.

QUALITY ASSURANCE

Canada

In order to ensure credibility of data in the Acid Rain Program, inter-laboratory studies are routinely carried out. This external quality assurance program has addressed the laboratory measurement process and audits the long-term performance of laboratories. Three inter-laboratory performance evaluation studies (10 samples for about 22 constituents) have been presented annually, since 1982, in addition to one study on vegetation annually (10 samples for about 25 constituents). The routine provision of these studies is believed to have created an atmosphere conducive to improvements to the measurement process.



Impact of external QA on the performance of one laboratory.

Evidence from these studies during 1990 and 1991 indicates that improvements in the measurement process continue to take place. An example of how one laboratory's performance has improved due to participation in a quality assurance program is shown in Figure 13. The data base management system that has archived over 30 large inter-comparison studies is viewed as a valuable resource for use by data users. This information base includes inter-laboratory results from over 100 Canadian and 25 American laboratories.

United States

Quality assurance was an integral part of the NAPAP process. Information on a number of quality assurance activities can be found in the NAPAP documents.

In 1990 and 1991, EPA conducted performance audits on 50 percent of the 3,700 air samplers being operated by 169 air pollution control agencies in the United States as part of the State and Local Air Monitoring Network. In these audits, which began in 1975, each agency received performance evaluation samples that they introduced as blind unknowns into their CO, NO_2, SO_2, O_3, Pb, and PM-10 samplers. Similar audits also were done on the large variety of stationary sources that emit toxic and acidic pollutants. Other audits included special studies measuring the deposition of toxic compounds into the Great Lakes and on several large-scale acid precipitation monitoring networks.

CONTROL TECHNOLOGIES

In Article VII of the Air Quality Agreement, Canada and the United States have agreed to "exchange, on a regular basis and through the Air Quality Committee established under Article VIII, information on. . . technologies, measures and mechanisms for controlling emissions." Annex 2 further specifies that the two countries agree to cooperate and exchange information regarding their development and demonstration of technologies and measures for controlling emissions of air pollutants, in particular acidic deposition precursors, subject to their respective laws, regulations, and policies.

Canada

In general, control efforts in Canada have been directed towards the non-ferrous smelters and fossil fuel burning power plants which produced about 60 and 20 percent, respectively, of Canada's SO_2 emissions in 1985.

In conjunction with government, the targeted smelters have researched, developed, and are implementing major technological improvements including increased phyrrotite rejection, advanced milling and beneficiation, zinc pressure leaching, and advanced smelting processes. Sulphur emissions are being effectively captured as liquid SO_2 and acid; both are marketable products. By 1994, these new facilities, costing nearly $900 million, will enable the smelters to meet their targets.

The federal and provincial governments, in cooperation with the electric power utilities, continue to conduct research and development on fuels, advanced combustion, and flue gas control technologies. Areas of recent research and development on SO_2 control for power plants include the following:

- Development of furnace sorbent injection systems and tests in Ontario and Saskatchewan.
- Trial burns of low sulphur fuels and flue gas conditioning systems in Ontario.
- Trial burns of Orimulsion (water-bitumen blend) fuel in New Brunswick.
- Development and trials of a low NOx/SOx (LNS) burner in Alberta.
- Development and testing of the SONOx process in Ontario.
- Development and trials of the Union Carbide CANSOLVE process in Alberta.
- Development and operation of an atmospheric fluidized bed combustion demonstration unit to burn high sul-

The original recommendation for a multi-billion dollar clean coal demonstration program came in 1986 from the U.S. and Canadian Special Envoys on Acid Rain after studying ways to resolve concerns between the two nations over the transboundary problem of acid rain.

phur coal, petroleum coke, oil shale, wood waste, and other fuels at Chatham, New Brunswick.

Government/industry research programs on SO_2 and NOx emission control are expected to continue in the coming years. Canada's Green Plan contains a major initiative on "Technology for Solutions" to assist in these further research efforts.

United States

While the United States had a pollution control technology program for many years, the original recommendation for a multi-billion dollar clean coal demonstration program came in 1986 from the U.S. and Canadian Special Envoys on Acid Rain after studying ways to resolve concerns between the two nations over the transboundary problem of acid rain. Consensus was that demonstration of innovative control technologies should lead to some near-term reductions in sulphur dioxide and nitrogen oxides, and, subsequently, in acid rain.

Begun by Congress in 1986 and expanded by two Presidential administrations, the Clean Coal Technology (CCT) Program is expected to finance more than $5 billion of projects when completed in the 1990s. The resulting power generating and pollution control technologies are products of years of research and development in numerous government and private laboratories. Lead by the U.S. Department of Energy, the CCT is a co-funded effort by government and industry to demonstrate the utility and merit of new coal burning processes in a series of full-scale commercial facilities. Canada was represented on the Innovative Coal Technology Assessment Panel, set up to provide advice and recommendations on projects. The program will take the most promising of the advanced coal-based technologies and, over the next decade and beyond, move them into the commercial marketplace.

CCT represents a fundamental change in coal-fired power plant technology. Projects in the CCT offer lower sulphur dioxide and/or nitrogen oxides emission levels than does conventional pulverized coal combustion. Some offer substantially lower emissions than even scrubber-equipped plants. In many cases, emission reductions and cost improvements are achieved concurrently as these technologies are expected to operate more efficiently than conventional plants. Finally, while conventional scrubbing produces large amounts of solid waste which must be disposed of, some clean coal technologies also are very low waste generators or provide easily recycled waste.

The CCT is being implemented through a total of five competitive solicitations, four of which have been completed. Each solicitation maintains a strong emphasis on mitigation of the acid rain precursor emissions of sulphur dioxide and nitrogen oxides, consistent with the recommendations of the U.S. and Canadian Special Envoys on Acid Rain. Objectives include demonstrating the feasibility of future commercial applications and significant reduction of sulphur dioxide and/or nitrogen oxides from existing facilities; providing future energy needs in an environmentally acceptable manner; and demonstrating technologies capable of retrofitting, repowering, or replacing existing facilities while achieving all of the above. Projects vary in design, in target percent emissions

reduction, and in commercial application and availability. Percent reduction, for example, ranges from 70 to 99 percent for sulphur dioxide and 50 to 95 percent for nitrogen oxides.

There are currently 42 active projects in the CCT Program. Three projects have been completed. There are 19 projects in the design phase or under construction and 10 in operation. The remaining 10 projects are in negotiation. By the year 2000, of the 33 projects selected under the first three CCT solicitations, 30 will have completed operation and be commercially available. Approximately six of the nine projects selected should have completed their operational phase and also be commercially available. The schedules for Round 4 projects are tentative and subject to final negotiation. When the projects are completed, the sponsors and participants will be in a position to use the information and experience gained during demonstrations to promote and market the technologies in commercial applications.

Total project costs through the first four solicitations under the program amount to approximately $4.4 billion, which includes a government share of $1.8 billion.

Canada and the United States hold an annual meeting on control technologies under a Memorandum of Understanding. During this meeting, all CCT publications (Program Update, Comprehensive Reports to Congress, Topical reports, etc.) are made available to the Canadian representatives. Canadian agencies participating in the exchange include CANMET and the Alberta Research Council.

MARKET-BASED MECHANISMS

In Annex 2 of the Air Quality Agreement, Canada and the United States agreed to cooperate and exchange information regarding their analysis of market-based mechanisms, including emissions trading.

Each country is exploring the use of market-based incentives for environmental policy, because, in appropriate applications, these tools offer the promise of achieving environmental goals more effectively at less cost. In the United States, market-based incentives are currently in use in the acid rain control program (as described above in this report) and in the program to phase out chlorofluorocarbon (CFC) production. Market incentives also were used successfully to phase out leaded gasoline.

Within the mandate of the Canadian Council of Ministers of the Environment (CCME) is the consideration of non-regulatory mechanisms for managing air emissions in Canada such as the use of emissions trading. To this end, two working groups were established under CCME, one for NOx/VOC and one for SO_2. The two groups developed in the fall of 1991 a policy paper entitled "Emission Trading: A Canadian Policy Framework." This paper summarizes the concept of emission trading and the results of a consultant's study on some of the U.S. experience with emission trading, but it mainly focuses on policy, administrative, and program design issues. This preliminary work is being followed up with a more detailed examination of the design of trading systems for NOx/VOCs in the Lower Fraser Valley

Region of British Columbia and for NOx in the Ontario portion of the Windsor-Quebec corridor. Work is under way to examine the feasibility and design of national or regional emission trading systems as a means of managing the national SO_2 emission cap. The work is expected to be completed by the end of 1992.

Canada and the United States are holding a series of meetings to share analyses of market-based incentives for environmental protection. Following initial consultations in Ottawa in December 1990, EPA hosted a meeting on this topic in December 1991 in Washington, attended by Environment Canada and representatives of several agencies of each government. The meeting discussed the experience gained in the United States in implementation of the lead phase down and the acid rain programs, as well as plans for emission trading in southern California to address urban air quality. Canada indicated its interest in using market incentives to address regional acid rain and urban air quality issues, the latter particularly in the Vancouver and Windsor-Quebec areas.

The two countries will continue meeting and sharing information on market-based incentives on an ongoing basis. The December 1991 meeting identified as key areas for future cooperation and information exchange acid rain, urban ozone, Great Lakes water quality, and options for cost-effective greenhouse gas emissions abatement. Since each of these issues can involve emission sources and/or pollution dispersion across a shared border, the possibility of including both U.S. and Canadian sources in a market-based incentive program also will be expanded.

Conclusion

This is the first progress report under the United States-Canada Air Quality Agreement. Since the signing of the Agreement in March 1991, the two countries have taken significant steps towards fulfilling the letter and the spirit of the Agreement. They have formed a bilateral Air Quality Committee and two subcommittees to assist in carrying out the terms of the Agreement. They have initiated, continued, and expanded working relationships in a variety of areas related to North American air quality. Most importantly, there has been a free exchange of people and information across our borders. While such exchanges occurred prior to the signing of the Air Quality Agreement, the number of contacts and the degree of cooperation and exchange of information have increased significantly, to the benefit of both countries.

Canada and the United States are making considerable progress in implementing programs aimed at the reduction of sulphur dioxide and nitrogen oxides. In Canada, the Eastern Canada Acid Rain Control Program is well on its way toward meeting its goals in 1994. In the United States, there has been considerable progress in promulgating the regulations that will implement the acid rain control provisions of the CAA. Both countries are sharing information with the other on a variety of issues related to program implementation, including the use of market-based incentives to achieve more cost-effective emission reductions.

Both countries are continuing a variety of scientific and technical activities and are coordinating/cooperating with one another in a number of areas, including emission inventories, atmospheric modeling, deposition monitoring, effects research and monitoring, human health, and control technologies.

The next progress report under the Air Quality Agreement is due out in 1994. Over the next two years, Canada and the United States will continue to implement their respective control programs and to share information with one another on their respective experiences as they approach important emission reduction milestones.

Future research and monitoring efforts related to acidic deposition include the following:

- Providing up-to-date inventories of total sulphur dioxide and nitrogen oxides emissions.
- Measuring air quality and deposition values and refining the predictive capabilities of atmospheric models.
- Recording the chemical and biological improvements in surface waters and responses to changing deposition.
- Determining the role of nitrogen deposition in ecosystem processes and the implications for control of acidification of surface waters.
- Resolving the role of acidic deposition in the forest decline problem.
- Evaluating the human health effects of acid aerosols and related pollutants.

Much of this work will be carried out jointly or cooperatively by Canadian and American scientists over the next several years. Progress in these areas will be reported in 1994.

APPENDIX A

United States-Canada Air Quality Committee

CANADIAN MEMBERS

Co-chair
Peter M. Higgins
Assistant Deputy Minister
Conservation and Protection
Environment Canada

H.A. (Tony) Clarke
Director General
Environmental Protection
Environment Canada

Phil Merilees
Director General
Atmospheric Research Directorate
Environment Canada

John Lowe
Director, International Trade
and U.S. Relations
Energy Policy Branch
Energy, Mines and Resources

David McLellan
Deputy Director
U.S. Transboundary Division
External Affairs and International Trade
Canada

Larry Lechner
Director, Air and Land Protection Branch
Saskatchewan Environment and
Public Safety

Ed Piche
Director, Air Resources Branch
Ontario Ministry of the Environment

Laval Lapointe
Acid Rain Coordinator
Ministrere de l'Environment
Gouvernement du Quebec

Creighton Brisco
Manager, Air Quality Branch
Nova Scotia Department of the
Environment

U.S. MEMBERS

Co-chair
Richard J. Smith
Principal Deputy Assistant Secretary
Bureau of Oceans and International
Environmental and Scientific Affairs
Department of State

Robert H. Pines
Deputy Assistant Secretary for
Canadian Affairs
Department of State

Eileen Claussen
Director, Office of Atmospheric and
Indoor Air Programs
Environmental Protection Agency

David Kee
Director, Air and Radiation Division
Region 5
Environmental Protection Agency

Howard Gruenspecht
Associate Deputy Undersecretary for
Program Analysis
Department of Energy

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Richard Williamson
Associate Deputy Assistant
Secretary for International Affairs
Department of Energy

Edward Cassidy
Deputy Chief of Staff and Deputy
Assistant Secretary for Policy
Department of Interior

Bruce Hicks
Director, Air Resources Laboratory
Department of Commerce/NOAA

Scott Farrow
Associate Director for Pollution Control
and Prevention
Council of Environmental Quality

SUBCOMMITTEE ON PROGRAM MONITORING AND REPORTING

Co-chairs:
Wayne Draper
Associate Director (Air)
Industrial Programs Branch
Environment Canada

Brian McLean
Director, Acid Rain Division
Office of Atmospheric and Indoor Air
Programs
Office of Air and Radiation
Environmental Protection Agency

SUBCOMMITTEE ON SCIENTIFIC COOPERATION

Co-chairs:
Tom Brydges
Director, Environmental Integration
Services Branch
Atmospheric Environment Service
Environment Canada

Jack Puzak
Deputy Director, Office of Modeling,
Monitoring Systems, and Quality
Assurance
Office of Research and Development
Environmental Protection Agency

TERMS OF REFERENCE

U.S.-Canada Air Quality Committee

1. Review progress made in the implementation of the Agreement, including its general and specific objectives.
2. Prepare and submit to the Parties a progress report within a year after entry into force of the Agreement and at least every two years thereafter.
3. Refer each progress report to the International Joint Commission for action in accordance with Article IX of the Agreement.
4. Release each progress report to the public after its submission to the Parties.
5. Establish reporting subcommittees as required to fulfill the above responsibilities.
6. Meet at least once a year and additionally at the request of either Party.
7. Not release, without the consent of the owner, any information identified to it as proprietary information under the laws of the place where such information has been acquired.

TERMS OF REFERENCE

Subcommittee on Program Monitoring and Reporting

1. Coordinate activities as outlined in paragraph 2 of Annex 2 to the Agreement for the purpose of determining and reporting on air emission levels, historical trends, and projections.

2. Cooperate and exchange information on development and demonstration of technologies and measures for controlling emissions of air pollutants, in particular, acidic deposition precursors, subject to respective laws, regulations, and policies, as set forth in subparagraph 3(d) of Annex 2 to the Agreement.

3. Cooperate and exchange information on their analysis of market-based mechanisms, including emission trading, as set forth in paragraph 3(e) of Annex 2 to the Agreement.

4. Cooperate and exchange information with respect to economic research that the Parties may agree upon for purposes of supporting the general and specific objectives of the Agreement, as set forth in paragraph 3(f) of Annex 2 to the Agreement.

5. Develop and revise, as necessary, recommendations to the Air Quality Committee on operational guidelines for implementation of Article V(2), and cooperate and exchange information regarding implementation of sections 3 and 4 of Annex 1 to the Agreement.

6. Assist the Air Quality Committee in reviewing progress made in the implementation of the Agreement, including its general and specific objectives, as required under Article VIII of the Agreement, with respect to areas within its purview.

7. Prepare necessary input on issue areas within its purview for the reports of the Air Quality Committee required under Article VIII of the Agreement.

8. Support the Air Quality Committee in its preparation of the report required under Article VIII.

9. Establish ad hoc bilateral working groups as may be required to fulfill the above responsibilities.

TERMS OF REFERENCE

Subcommittee on Scientific Cooperation

1. Coordinate air pollutant monitoring activities as set forth in paragraph 1 of Annex 2 to the Agreement for the purpose of determining and reporting on air pollutant concentrations and deposition.

2. Cooperate and exchange information on their monitoring of the effects of changes in air pollutant concentration and deposition, with respect to changes in various effects categories, e.g., aquatic ecosystems, visibility, and forests, as set forth in subparagraph 3(a) of Annex 2 to the Agreement.

3. Cooperate and exchange information on their determination of any effects of atmospheric pollution on human health and ecosystems, as set forth in subparagraph 3(b) of Annex 2 to the Agreement.

4. Cooperate and exchange information on the development and refinement of atmospheric models for purposes of determining source receptor relationships and transboundary transport and deposition of air pollutants, as set forth in subparagraph 3(c) of Annex 2 to the Agreement.

5. Consult on approaches to, and share information and results of research on, methods to mitigate the impacts of acidic deposition, including the environmental effects and economic aspects of such methods, as set forth in paragraph 4 of Annex 2 to the Agreement.

6. Cooperate and exchange information with respect to any other scientific or technical activities that the Parties ask it to undertake to support the general and specific objectives of the Agreement.

7. Prepare the necessary scientific input for the reports of the Air Quality Committee as required under Article VIII of the Agreement.

8. Establish ad hoc bilateral working groups as may be required to fulfill the above responsibilities.

Agreement between the Government of the United States of America and the Government of Canada on Air Quality

The Government of the United States of America and the Government of Canada, hereinafter referred to as "the Parties,"

Convinced that transboundary air pollution can cause significant harm to natural resources of vital environmental, cultural and economic importance, and to human health in both countries;

Desiring that emissions of air pollutants from sources within their countries not result in significant transboundary air pollution;

Convinced that transboundary air pollution can effectively be reduced through cooperative or coordinated action providing for controlling emissions of air pollutants in both countries;

Recalling the efforts they have made to control air pollution and the improved air quality that has resulted from such efforts in both countries;

Intending to address air-related issues of a global nature, such as climate change and stratospheric ozone depletion, in other fora;

Reaffirming Principle 21 of the Stockholm Declaration, which provides that "States have, in accordance with the Charter of the United Nations and the principles of international law, the sovereign right to exploit their own resources pursuant to their own environmental policies, and the responsibility to ensure that activities within their jurisdiction or control do not cause damage to the environment of other States or of areas beyond the limits of national jurisdiction";

Noting their tradition of environmental cooperation as reflected in the Boundary Waters Treaty of 1909, the Trail Smelter Arbitration of 1941, the Great Lakes Water Quality Agreement of 1978, as amended, the Memorandum of Intent Concerning Transboundary Air Pollution of 1980, the 1986 Joint Report of the Special Envoys on Acid Rain, as well as the ECE Convention on Long-Range Transboundary Air Pollution of 1979;

Convinced that a healthy environment is essential to assure the well-being of present and future generations in the United States and Canada, as well as of the global community;

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Have agreed as follows:

ARTICLE I

Definitions

For the purposes of this Agreement:

1. "Air pollution" means the introduction by man, directly or indirectly, of substances into the air resulting in deleterious effects of such a nature as to endanger human health, harm living resources and ecosystems and material property and impair or interfere with amenities and other legitimate uses of the environment, and "air pollutants" shall be construed accordingly;

2. "Transboundary air pollution" means air pollution whose physical origin is situated wholly or in part within the area under the jurisdiction of one Party and which has adverse effects, other than effects of a global nature, in the area under the jurisdiction of the other Party;

3. "Boundary Waters Treaty" means the Treaty Relating to Boundary Waters and Questions Arising along the Boundary between the United States and Canada, signed at Washington on January 11, 1909;

4. "International Joint Commission" means the International Joint Commission established by the Boundary Waters Treaty.

ARTICLE II

Purpose

The purpose of the Parties is to establish, by this Agreement, a practical and effective instrument to address shared concerns regarding transboundary air pollution.

ARTICLE III

General Air Quality Objective

1. The general objective of the Parties is to control transboundary air pollution between the two countries.

2. To this end, the Parties shall:

   (a) in accordance with Article IV, establish specific objectives for emissions limitations or reductions of air pollutants and adopt the necessary programs and other measures to implement such specific objectives;

   (b) in accordance with Article V, undertake environmental impact assessment, prior notification, and, as appropriate, mitigation measures;

   (c) carry out coordinated or cooperative scientific and technical activities, and economic research, in accordance with Article VI, and exchange information, in accordance with Article VII;

   (d) establish institutional arrangements, in accordance with Articles VIII and IX; and

   (e) review and assess progress, consult, address issues of concern, and settle disputes, in accordance with Articles X, XI, XII, and XIII.

ARTICLE IV

Specific Air Quality Objectives

1. Each Party shall establish specific objectives, which it undertakes to achieve, for emissions limitations or reductions of such air pollutants as the Parties agree to address. Such specific objectives will be set forth in annexes to this Agreement.

2. Each Party's specific objectives for emissions limitations or reductions of sulphur dioxide and nitrogen oxides, which will reduce transboundary flows of these acidic deposition precursors, are set forth in Annex 1. Specific objectives for such other air pollutants as the Parties agree to address should take into account, as appropriate, the activities undertaken pursuant to Article VI.

3. Each Party shall adopt the programs and other measures necessary to implement its specific objectives set forth in any annexes.

4. If either Party has concerns about the programs or other measures of the other Party referred to in paragraph 3, it may request consultations in accordance with Article XI.

ARTICLE V

Assessment, Notification, and Mitigation

1. Each Party shall, as appropriate and as required by its laws, regulations and policies, assess those proposed actions, activities and projects within the area under its jurisdiction that, if carried out, would be likely to cause significant transboundary air pollution, including consideration of appropriate mitigation measures.

2. Each Party shall notify the other Party concerning a proposed action, activity or project subject to assessment under paragraph 1 as early as practicable in advance of a decision concerning such action, activity or project and shall consult with the other Party at its request in accordance with Article XI.

3. In addition, each Party shall, at the request of the other Party, consult in accordance with Article XI concerning any continuing actions, activities or projects that may be causing significant transboundary air pollution, as well as concerning changes to its laws, regulations or policies that, if carried out, would be likely to significantly affect transboundary air pollution.

4. Consultation pursuant to paragraphs 2 and 3 concerning actions, activities or projects that would be likely to cause or may be causing significant transboundary air pollution shall include consideration of appropriate mitigation measures.

5. Each Party shall, as appropriate, take measures to avoid or mitigate the potential risk posed by actions, activities or projects that would be likely to cause or may be causing significant transboundary air pollution.

6. If either Party becomes aware of an air pollution problem that is of joint concern and requires an immediate response, it shall notify and consult the other Party forthwith.

ARTICLE VI

Scientific and Technical Activities and Economic Research

1. The Parties shall carry out scientific and technical activities, and economic research, as set forth in Annex 2, in order to improve their understanding of transboundary air pollution concerns

and to increase their capability to control such pollution.

2. In implementing this Article, the Parties may seek the advice of the International Joint Commission regarding the conduct of monitoring activities.

ARTICLE VII

Exchange of Information

1. The Parties agree to exchange, on a regular basis and through the Air Quality Committee established under Article VIII, information on:

   (a) monitoring;

   (b) emissions;

   (c) technologies, measures and mechanisms for controlling emissions;

   (d) atmospheric processes; and

   (e) effects of air pollutants,

   as provided in Annex 2.

2. Notwithstanding any other provisions of this Agreement, the Air Quality Committee and the International Joint Commission shall not release, without the consent of the owner, any information identified to them as proprietary information under the laws of the place where such information has been acquired.

ARTICLE VIII

The Air Quality Committee

1. The Parties agree to establish and maintain a bilateral Air Quality Committee to assist in the implementation of this Agreement. The Committee shall be composed of an equal number of members representing each Party. It may be supported by subcommittees, as appropriate.

2. The Committee's responsibilities shall include:

   (a) reviewing progress made in the implementation of this Agreement, including its general and specific objectives;

   (b) preparing and submitting to the Parties a progress report within a year after entry into force of this Agreement and at least every two years thereafter;

   (c) referring each progress report to the International Joint Commission for action in accordance with Article IX of this agreement; and

   (d) releasing each progress report to the public after its submission to the Parties.

3. The Committee shall meet at least once a year and additionally at the request of either Party.

ARTICLE IX

Responsibilities of the International Joint Commission

1. The International Joint Commission is hereby given, by a Reference pursuant to Article IX of the Boundary Waters Treaty, the following responsibilities for the sole purpose of assisting the Parties in the implementation of this Agreement:

   (a) to invite comments, including through public hearings as appropriate, on each progress report prepared by the Air Quality Committee pursuant to Article VIII;

   (b) to submit to the Parties a synthesis of the views presented pursuant to sub-paragraph (a), as well as the record of such views if either Party so requests; and

(c) to release the synthesis of views to the public after its submission to the Parties.

2. In addition, the parties shall consider such other joint references to the International Joint Commission as may be appropriate for the effective implementation of this Agreement.

ARTICLE X

Review and Assessment

1. Following the receipt of each progress report submitted to them by the Air Quality Committee in accordance with Article VIII and the views presented to the International Joint Commission on that report in accordance with Article IX, the Parties shall consult on the contents of the progress report, including any recommendations therein.

2. The Parties shall conduct a comprehensive review and assessment of this Agreement, and its implementation, during the fifth year after its entry into force and every five years thereafter, unless otherwise agreed.

3. Following the consultations referred to in paragraph 1, as well as the review and assessment referred to in paragraph 2, the Parties shall consider such action as may be appropriate, including:

   (a) the modification of this Agreement;

   (b) the modification of existing policies, programs or measures.

ARTICLE XI

Consultations

The Parties shall consult, at the request of either Party, on any matter within the scope of this Agreement. Such consultations shall commence as soon as practicable, but in any event not later than 30 days from the date of receipt of the request for consultations, unless otherwise agreed by the Parties.

ARTICLE XII

Referrals

With respect to cases other than those subject to Article XIII, if, after consultations in accordance with Article XI, an issue remains concerning a proposed or continuing action, activity, or project that is causing or would be likely to cause significant transboundary air pollution, the Parties shall refer the matter to an appropriate third party in accordance with agreed terms of reference.

ARTICLE XIII

Settlement of Disputes

1. If, after consultations in accordance with Article XI, a dispute remains between the Parties over the interpretation or the implementation of this Agreement, they shall seek to resolve such dispute by negotiations between them. Such negotiations shall commence as soon as practicable, but in any event not later than 90 days from the date of receipt of the request for negotiation, unless otherwise agreed by the Parties.

2. If a dispute is not resolved through negotiation, the Parties shall consider whether to submit that dispute to the International Joint Commission in accordance with either Article IX or Article X of the Boundary Waters Treaty. If, after such consideration, the Parties do not elect either of those options, they shall, at the request of either Party, submit the dispute to another agreed form of dispute resolution.

ARTICLE XIV

Implementation

1. The obligations undertaken under this Agreement shall be subject to the availability of appropriated funds in accordance with the respective constitutional procedures of the Parties.
2. The Parties shall seek:
   (a) the appropriation of funds required to implement this Agreement;
   (b) the enactment of any additional legislation that may be necessary to implement this Agreement;
   (c) the cooperation of State and Provincial Governments as necessary to implement this Agreement.
3. In implementing this Agreement, the Parties shall, as appropriate, consult with State or Provincial Governments, interested organizations, and the public.

ARTICLE XV

Existing Rights and Obligations

Nothing in this Agreement shall be deemed to diminish the rights and obligations of the Parties in other international agreements between them, including those contained in the Boundary Waters Treaty and the Great Lakes Water Quality Agreement of 1978, as amended.

ARTICLE XVI

Entry into Force, Amendment, Termination

1. This Agreement, including Annexes 1 and 2, shall enter into force upon signature by the Parties.
2. This Agreement may be amended at any time by agreement of the Parties in writing.
3. Either Party may terminate this agreement upon one year's written notice to the other Party, in which case any annexes will also terminate.
4. Annexes constitute an integral part of this Agreement, except that, if an annex so provides, either Party may terminate such annex in accordance with the terms of that annex.

IN WITNESS WHEREOF, the undersigned have signed this Agreement.

DONE in duplicate, at Ottawa, this 13th day of March, 1991, in the English and French languages, each version being equally authentic.

FOR THE GOVERNMENT OF THE UNITED STATES OF AMERICA

POUR LE GOUVERNEMENT DES ESTAS-UNIS D'AMERIQUE

EN FOI DE QUOI, les soussignes ont signe le present Accord.

FAIT en deux exemplaires a OTTAWA, ce 13e jour de mars, 1991, en langues anglaise et francaise, les deux versions faisant egalement foi.

FOR THE GOVERNMENT OF CANADA

POUR LE GOUVERNEMENT DU CANADA

ANNEX 1

Specific Objectives Concerning Sulphur Dioxide and Nitrogen Oxides

1. Sulphur Dioxide

A. For the United States:[1]

1. Reduction of annual sulphur dioxide emissions by approximately 10 million tons[2] from 1980 levels in accordance with Title IV of the Clean Air Act[3] i.e., reduction of annual sulphur dioxide emissions to approximately 10 million tons below 1980 levels by 2000 (with the exception of sources repowering with qualifying clean coal technology in accordance with section 409 of the Clean Air Act, and sources receiving bonus allowances in accordance with sections 405(a)(2) and (3) of the Clean Air Act).

2. Achievement of a permanent national emission cap of 8.95 million tons of sulphur dioxide per year for electric utilities by 2010, to the extent required by Title IV of the Clean Air Act.

3. Promulgation of new or revised standards or such other action under the Clean Air Act as the Administrator of the U.S. Environmental Protection Agency (EPA) deems appropriate, to the extent required by section 406 of the Clean Air Act Amendments of 1990 (P. L. 101-549), aimed at limiting sulphur dioxide emissions from industrial sources in the event that the Administrator of EPA determines that annual sulphur dioxide emissions from industrial sources may reasonably be expected to exceed 5.6 million tons.

B. For Canada:

1. Reduction of sulphur dioxide emissions in the seven easternmost Provinces to 2.3 million tonnes per year by 1994 and the achievement of a cap on sulphur dioxide emissions in the seven easternmost Provinces at 2.3 million tonnes per year from 1995 through December 31, 1999.

2. Achievement of a permanent national emissions cap of 3.2 million tonnes per year by 2000.

2. Nitrogen Oxides

A. For the United States[1]:

With a view to a reduction of total annual emissions of nitrogen oxides by approximately 2 million tons from 1980 emission levels by 2000:

1. Stationary Sources

Implementation of the following nitrogen oxides control program for electric utility boilers to the extent required by Title IV of the Clean Air Act:

(a) By January 1, 1995, tangentially fired boilers must meet an allowable emission rate of 0.45 lb/mmBtu, and dry bottom wall-fired boilers must meet an allowable emission rate of 0.50 lb/mmBtu (unless the Administrator of EPA determines that these rates cannot be achieved using low NOx burner technology).

1 - Applies only to reductions in emissions in the 48 contiguous states and the District of Columbia.

2 - 1 ton = 0.91 tonnes (metric tons).

3 - All references to the Clean Air Act refer to the Act as amended November 15, 1990.

(b) By January 1, 1997, EPA must set allowable emission limitations for:

- wet bottom wall-fired boilers;
- cyclones;
- units applying cell burner technology; and
- all other types of utility boilers.

2. Mobile Sources

Implementation of the following mobile source nitrogen oxides control program to the extent required by Title II of the Clean Air Act:

(a) Light Duty Trucks (LDT) (up to 6,000 lbs gross vehicle weight rating (GVWR)) and Light Duty Vehicles (LDV)—standards for model years after 1993:

	5 yrs/50,000 miles (useful life)	10 yrs/100,000 miles
LDTs (0 to 3,750 lbs Loaded Vehicle Weight (LVW)) and LDVs	0.4 grams per mile (gpm)	0.6 gpm
Diesel LDTs (0 to 3,750 lbs LVW) and LDVs (before 2004)	1.0 gpm	1.25 gpm
LDTs (3,751 to 5,750 lbs LVW)	0.7 gpm[4]	0.97 gpm

In model year 1994, 40 percent of each manufacturer's sales volume must meet the above standards. In 1995, the percentage shall increase to 80 percent and, after 1995, to 100 percent.

(b) Light Duty Trucks more than 6,000 lbs GVWR (after model year 1995):

	Gasoline 5 yrs/50,000 miles	Gasoline and Diesel 11 yrs/ 120,000 miles
LDTs (3,751 to 5,750 lbs Test Weight (TW))	0.7 gpm	0.98 gpm
LDTs (over 5,750 lbs TW)	1.1 gpm	1.53 gpm

In model year 1996, 50 percent of each manufacturer's sales volume must meet the above standards. Thereafter, 100 percent of each manufacturer's sales volume must meet the standard.

(c) Heavy Duty Trucks (HDT) of more than 8,500 lbs GVWR (after model year 1990):

	Gasoline and Diesel Engines
HDT (effective model year 1991[5])	5.0 grams per brake horsepower-hour[5] (gbhp-hr)
HDT (model year 1998 and later)	4.0 gbhp-hr

Useful life[5]:

Gasoline Engines	8 yrs/110,000 miles
Diesel Engines	
Light heavy-duty	8 yrs/110,000 miles
Medium heavy-duty	8 yrs/185,000 miles
Heavy heavy-duty	8 yrs/290,000 miles

4 - This standard does not apply to diesel-fueled LDTs (3,751 to 5,750 lbs LVW).

5 - As set forth in EPA regulations in effect as of the entry into force of this Agreement.

B. For Canada:

1. Stationary Sources

(a) As an interim requirement, reduction, by 2000, of annual national emissions of nitrogen oxides from stationary sources by 100,000 tonnes below the year 2000 forecast level of 970,000 tonnes.

(b) By January 1, 1995, development of further annual national emission reduction requirements from stationary sources to be achieved by 2000 and/or 2005.

2. Mobile Sources

(a) Implementation of a more stringent mobile source nitrogen oxides control program for gasoline-powered vehicles with standards no less stringent than the following:

Light Duty Vehicles (up to 6,000 lbs GVWR) (By model year 1996 for passenger cars; by model year 1996 for light duty trucks[6]):

	5 yrs/80,000 kilometers (useful life)
Cars and Light Duty Trucks (0 to 3,750 lbs LVW)	0.4 gpm
Light Duty Trucks (3,751 to 5,750 lbs LVW)	0.7 gpm

Medium Duty Vehicles (6,001 to 8,500 lbs GVWR) (By model year 1997[6]):

	5 yrs/80,000 kilometers (useful life)
0 to 3,750 lbs LVW	0.4 gpm
3,751 to 5,750 lbs LVW	0.7 gpm
Over 5,750 lbs LVW	1.1 gpm

Heavy Duty Vehicles (over 8,500 lbs GVWR) (By model year 1998[6]):

	8 yrs/110,000 kilometers (useful life)
Over 8,500 lbs GVWR	4.0 gbhp-hr

(b) Implementation of a more stringent mobile source nitrogen oxides control program for diesel-powered vehicles and engines with standards, to the extent possible, no less stringent than the standards for the respective duty classes of gasoline-powered vehicles and engines.

3. Compliance Monitoring

A. Utility Units

1. For the United States:

Requirement that, by January 1, 1995, each new electric utility unit and each electric utility unit greater than 25 MWe existing on the date of enactment of the Clean Air Act amendments of

6 - The Government of Canada will propose this effective date; the final effective date is subject to the procedures and outcome of the regulation development process.

1990 (November 15, 1990) emitting sulphur dioxide or nitrogen oxides install and operate continuous emission monitoring systems or alternative systems approved by the Administrator of EPA, to the extent required by section 412 of the Clean Air Act.

2. **For Canada:**

   Requirement that, by January 1, 1995, Canada estimate sulphur dioxide and nitrogen oxides emissions from each new electric utility unit and each existing electric utility unit greater than 25 MWe using a method of comparable effectiveness to continuous emission monitoring, as well as investigate the feasibility of using and implement, where appropriate, continuous emission monitoring systems.

3. **For Both Parties:**

   The Parties shall consult, as appropriate, concerning the implementation of the above.

B. Other Major Stationary Sources

Requirement that the Parties work towards utilizing comparably effective methods of emission estimation for sulphur dioxide and nitrogen oxides emissions from all major industrial boilers and process sources, including smelters.

4. Prevention of Air Quality Deterioration and Visibility Protection

Recognizing the importance of preventing significant air quality deterioration and protecting visibility, particularly for international parks, national, state, and provincial parks, and designated wilderness areas:

A. For the United States:

Requirement that the United States maintain means for preventing significant air quality deterioration and protecting visibility, to the extent required by Part C of Title I of the Clean Air Act, with respect to sources that could cause significant transboundary air pollution.

B. For Canada:

Requirement that Canada, by January 1, 1995, develop and implement means affording levels of prevention of significant air quality deterioration and protection of visibility comparable to those in paragraph A above, with respect to sources that could cause significant transboundary air pollution.

C. For Both Parties:

The Parties shall consult, as appropriate, concerning the implementation of the above.

ANNEX 2

Scientific and Technical Activities and Economic Research

For the purpose of determining and reporting on air pollutant concentrations and deposition, the Parties agree to coordinate their air pollutant monitoring activities through:

(a) coordination of existing networks;

(b) additions to monitoring tasks of existing networks of those air pollutants that the Parties agree should be monitored for the purposes of this Agreement;

(c) addition of stations or networks where no existing monitoring facility can perform a necessary function for purposes of this Agreement;

(d) the use of compatible data management procedures, formats, and methods; and

(e) the exchange of monitoring data.

2. For the purpose of determining and reporting air emissions levels, historical trends, and projections with respect to the achievement of the general and specific objectives set forth in this Agreement, the Parties agree to coordinate their activities through:

(a) identification of such air emissions information that the Parties agree should be exchanged for the purposes of this Agreement;

(b) the use of measurement and estimation procedures of comparable effectiveness;

(c) the use of compatible data management procedures, formats, and methods; and

(d) the exchange of air emission information.

3. The Parties agree to cooperate and exchange information with respect to:

(a) their monitoring of the effects of changes in air pollutant concentrations and deposition with respect to changes in various effects categories, e.g., aquatic ecosystems, visibility, and forests;

(b) their determination of any effects of atmospheric pollution on human health and ecosystems, e.g., research on health effects of acid aerosols, research on the long-term effects of low concentrations of air pollutants on ecosystems, possibly in a critical loads framework;

(c) their development and refinement of atmospheric models for purposes of determining source receptor relationships and transboundary transport and deposition of air pollutants;

(d) their development and demonstration of technologies and measures for controlling emissions of air pollutants, in particular acidic deposition precursors, subject to their respective laws, regulations and policies;

(e) their analysis of market-based mechanisms, including emission trading; and

(f) any other scientific and technical activities or economic research that the Parties may agree upon for purposes of supporting the general and specific objectives of this Agreement.

4. The Parties further agree to consult on approaches to, and share information and results of research on, methods to mitigate the impacts of acidic deposition, including the environmental effects and economic aspects of such methods.

Article IX of the United States-Canada Air Quality Agreement assigns the International Joint Commission the responsibility of soliciting comments on this Progress Report. You may send written comments to either of the following:

IN THE UNITED STATES

Secretary, U.S. Section
International Joint Commission
1250 23rd Street, NW
Suite 100
Washington, DC 20440

IN CANADA

Secretary, Canadian Section
International Joint Commission
100 Metcalfe Street
18th Floor
Ottawa, Ontario K1P 5M1

If you are interested in obtaining information on the scientific and technical issues of acid deposition, contact:

IN THE UNITED STATES

National Acid Precipitation
Assessment Program
722 Jackson Place, NW
Washington, DC 20503

IN CANADA

Environmental Integration
Services Branch
Environment Canada
4905 Dufferin Street
Downsview, Ontario M3H 5T4

If you are interested in obtaining information on the acid deposition control programs, contact:

IN THE UNITED STATES

Acid Rain Division
U.S. Environmental Protection Agency
Mail Code: 6204J
401 M Street, SW
Washington, DC 20460

IN CANADA

Acid Rain Program
Industrial Programs Branch
Environment Canada
351 St. Joseph Boulevard
Place Vincent Massey - 13th Floor
Hull, Quebec K1A 0H3